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Biological Services Program

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GRAVEL REMOVAL GUIDELINES MANUAL FOR ARCTIC AND SUBARCTIC FLOODPLAINS

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June 1980

GRAVEL REMOVAL GUIDELINES MANUAL FOR ARCTIC AND SUBARCTIC FLOODPLAINS

U.S. FISH AND WILDLIFE SERVICE

by

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DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not reflect the views of the Office of Biological Services, Fish and Wildlife Service or the Office of Research and Development, U.S. Environmental Protection Agency.

INTRODUCTION

A study was initiated in mid-1975 to evaluate the effects of gravel removal from arctic and subarctic floodplains in Alaska. The primary purpose of the project was to provide an information base to assist resource managers in formulating recommendations that would minimize detrimental environmental effects of gravel removal from floodplain material sites. To achieve this objective 25 material sites were studied by a team of scientists and engineers. Three major products resulted from the study. They are: (1) a Technical Report presenting synthesis and evaluation of the data collected at the sites, (2) a Guidelines Manual that aids the user in developing plans and operating material sites to minimize environmental effects, and (3) a Data Base filed with the U. S. Fish and Wildlife Service in Anchorage containing raw and reduced data, aerial and ground photographs, and other relevant material from each site. This report is the Guidelines Manual.

APPLICABILITY OF THE GUIDELINES

It is important to recognize that the guidelines contained in this manual were developed from a study of 25 floodplain material sites in arctic and subarctic Alaska. Therefore, they deal neither generally nor specifically with material sites in upland or coastal situations. Similarly, they do not include evaluation of the relative acceptability of utilizing an existing active or abandoned material site or an abandoned structure containing gravel (such as a drill pad or airstrip) rather than a floodplain site. This should not be interpreted as recommending sites in floodplains over other locations. WHEN A NEED FOR GRAVEL HAS BEEN IDENTIFIED, ALL ALTERNATIVES SHOULD BE CONSIDERED. ONLY AFTER A FLOODPLAIN HAS BEEN SELECTED FOR THE PROPOSED MATERIAL SITE DO THE GUIDELINES CONTAINED HEREIN BECOME APPLICABLE. However, if used cautiously some guidelines may be utilized in other site and regional situations.

The 25 material sites exhibited a range of variation in site age, gravel mining method and location; and river configuration, origin, and size. Selected sites were minimally affected by complicating factors such as nearby bridges, culverts, villages, and other material sites. The latter case is significant in the application of these guidelines. On large projects it is sometimes necessary to locate a series of material sites in close proximity along the floodplain of a river. The effects of multiple material sites in a floodplain were not evaluated in this study. Hence the application of these guidelines to multiple site projects must recognize this shortcoming.

The user should be thoroughly familiar with the contents of the Technical Report to give perspective to the guidelines for their effective use. THE GUIDELINES ARE DESIGNED TO DIRECT THE PROCESS OF IDENTIFYING, PLANNING, PREPARING, OPERATING, AND CLOSING MATERIAL SITES; THEY ARE NOT MEANT TO BE USED AS STIPULATIONS TO BE USED IN EACH AND EVERY CASE.

It is essential that the user of these guidelines consider each material site individually. Identification of unique characteristics may require that certain guidelines be ignored or interpreted differently, or different combinations of guidelines be considered. This manual is intended for use by all individuals interested in floodplain gravel removal.

GRAVEL REMOVAL METHODS AND CLASSIFICATION

A variety of gravel removal methods and river characteristics are covered by this manual. In general, these methods and river characteristics consist of:

1. Scraping exposed or vegetated gravel from active and inactive floodplain and terrace deposits. Scraping usually does not involve working in active channels.

2. Pit excavation of vegetated gravel deposits located in inactive floodplains and terraces.

3. Dredging from the bed of active channels of large and medium-sized rivers.

SUMMARY OF PROJECT RESULTS AND CONCLUSIONS

Study of 25 floodplain material sites has shown that disturbance resulting from gravel removal operations can be minimized. Two gravel mining techniques were used at the study sites, scraping of surface or near-surface deposits and pit excavation of deep deposits.

In general, approaches to minimize environmental changes caused by scraping included maintaining buffers between active channels and the work area and avoiding:

- Instream work
- Mining to depths and in locations that induce permanent channel shifts or ponding of water
- Clearing of riparian vegetation
- Disturbance to natural banks

Large rivers and braided rivers generally provide the most accessible gravels for scraping. Gravel mining using scraping technqiues in these areas frequently resulted in the least environmental changes.

Pit excavations resulted in permanent loss of terrestrial riparian habitat, however, many pits increased local habitat diversity. These newly created habitats frequently received concentrated utilization by local fauna, particularly fish, waterfowl, shorebirds, and furbearers. Large quantities of material were excavated using pit mining techniques. Pits that were located on the inactive side of the floodplain, and were separated by vegetated buffers in the range of 50 to 100 m, generally did not influence active channel hydraulics.

Pits were found to be most beneficial to local fauna when they exhibited the following characteristics:

- 2 ha or more in size
- Contained diverse shoreline configuration
- Contained diverse water depths
- Contained islands
- Contained an outlet connected to active channels

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PROCEDURES FOR GUIDELINE USE

To use this manual it is necessary to acquire information on site location, operation, and environmental conditions. The information consists of descriptions of the site and gravel removal methods that will allow prediction of floodplain changes.

The manual is divided into seven sections based primarily on the order in which a site will be selected, reviewed, and worked (Figure 1). Although site selection is the primary topic of Section I, much of the information in the other sections is also valuable in selecting appropriate mining locations and methods. For this reason, the entire manual should be read and clearly understood before deciding on a final work plan. For example, much of the information in Section VI - SITE OPERATION can be valuable in determining where selection of a specific method or location may increase the amount of available material while decreasing environmental alteration.

After the guidelines have been thoroughly reviewed, it is recommended the sequence presented below should be followed.

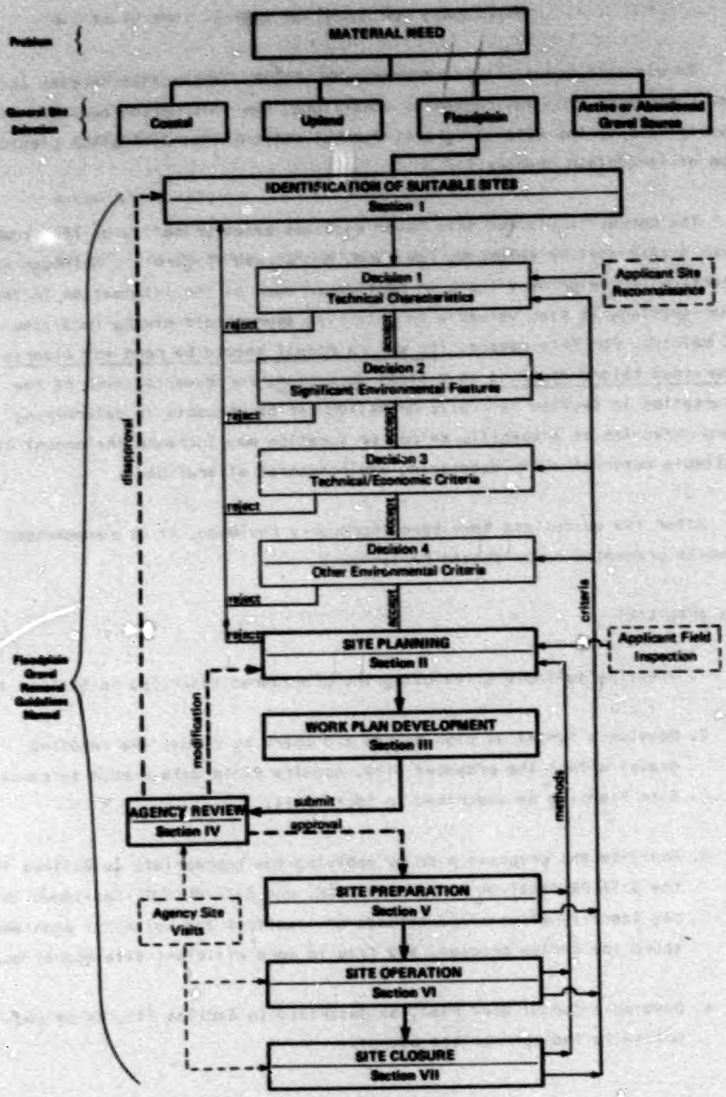
SITE APPLICANT

1. Identify suitable sites using the procedures described in Section I.

2. Develop a tentative plan on how and where to remove the required gravel within the proposed site. Acquire field data needed to complete Site Planning as described in Section II.

3. Evaluate the proposed plan by applying the appropriate guidelines from the SITE PREPARATION, SITE OPERATION, and SITE CLOSURE Sections. This may identify alternative methods or locations and potential problems, speed the review process, and lead to more efficient site operation.

4. Develop a formal Work Plan, as described in Section III, to be submitted to the appropriate agency.


Problem
MATERIAL NEED
General Site Selection
Coastal
Upland
Floodplain
Active or Abandoned Gravel Source
IDENTIFICATION OF SUITABLE SITES
Section I
Decision 1
Technical Characteristics
Applicant Site Reconnaissance
reject
accept
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reject
accept
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reject
accept
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reject
accept
criteria
disapproval
reject
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Section II
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Section VII

Figure 1. Gravel mining planning and implementation.

5. Work and close the site in accordance with the appropriate guidelines and approved Work Plan.

SITE REVIEWER

1. After receiving a work plan completed in accordance with Sections I through III, evaluate the plan and site location for the presence of significant environmental features identified in Section IV.

2. Visit the site to evaluate the technical feasibility, proposed boundaries, habitat quality, and possible environmental concerns.

3. Use Sections V through VII to evaluate the Work Plan and suggest modifications, if appropriate.

4. Following approval, conduct site visits during operation and closure to check adherence to the approved Work Plan.

Gravel Removal Guidelines

Identification of Suitable Sites
Section I

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Identification of Suitable Sites
Section I

A. GENERAL GUIDELINES

A number of factors influence the suitability of a gravel removal site. Among these are:

- Technical Requirements - such as quantity and quality of available material, required processing (washing of fines)
- Economics - such as hauling distance, and site preparation and rehabilitation requirements (overburden removal, river-training structures, and site grading)
- Environmental Characteristics - including location within the floodplain, and biological characteristics of the site

Many projects require more than one type of material, and these types often will not be available from a single material site. Linear projects such as pipelines and roads will require sites spaced along their length. In regions where winter construction activities are required, stockpiling of gravel in summer may be necessary to provide material with lower moisture content.

B. SPECIFIC GUIDELINES

Because of the need to incorporate technical, economic, and environmental factors, siting decisions must be considered on a case-by-case basis. However, a sequence of four levels of decisions should be utilized in site selection. All levels should consider both previously undisturbed sites as well as previously mined sites. There may be occasions when previously mined sites are more suitable because of the presence of access roads, airstrips, removed overburden, and existing unused stockpiled material.

A preliminary site visit is appropriate to provide input to the following decisions.

1. Decision 1 - Technical Characteristics of Alternative Sites

Two initial steps are important in the site identification process.

a. Determine that the area can provide material meeting the technical and volumetric requirements of the project. These requirements must be obtainable within suitable buffers (refer to buffer recommendations in Section V A 3 and Appendix A).

b. Determine if more than one specific site that meets these requirements exists in the area

Failure to determine availability of suitable material can result in unnecessary economic cost and environmental damage if initial mining activities show a site to be unsuitable. It is desirable to identify alternative sites in an area of interest because not all sites will be acceptable.

2. Decision 2 - Areas or Species of Special Concern

The alternative sites identified in Decision 1 should be evaluated relative to their disturbance of the features listed below. A site affecting these areas should be modified, or in some cases discarded, to minimize or eliminate any effect.

a. Threatened or endangered species and their habitats that are deemed essential to the survival or recovery of these species that are recognized by Federal and State governments. A current listing of species and information as to their distribution may be obtained from the U. S. Fish and Wildlife Service or the State Fish and Game agency. Sites affecting these species or their habitats may be prohibited, or require substantial justification.

b. Habitats limiting local populations (such as fish spawning and overwintering habitats, Dall sheep lambing areas or raptor nesting habitats). Sites directly affecting these habitats should not be considered further unless alternate sites are not available.

c. Undercut vegetated banks and associated riparian zones

d. Incised vegetated banks and associated riparian zones, except for properly utilized access by fill ramps

e. Springs

f. Active channels in small rivers of meandering, sinuous, and straight configurations

g. Wetlands - The primary criteria most frequently used in wetland definitions include presence of water-saturated soil conditions, and vegetative communities adapted to such conditions. For current definition, delineation and jurisdiction refer to local offices of the U. S. Army Corps of Engineers.

h. Other Federal, State, and private lands with special use and regulation such as wilderness areas, parks, wildlife refuges, archaeological areas, and historical landmarks

3. Decision 3 - Technical and Economic Criteria

Following the determination that suitable material can be obtained from one or more sites without disturbance to areas or species of special concern, strong emphasis should be placed on selecting an economical site. Factors influencing this decision include:

a. Amount of site preparation and rehabilitation required. For instance, it is desirable to minimize:

- Haul distance to project site
- Vegetation and overburden removal
- River-training structures and bank protection devices
- Length of access route
- Crossing of active drainage or channels

b. Matching site operational requirements to available equipment

c. Ability to work the site in a dry condition

4. Decision 4 - Other Environmental Criteria

If at this point two or more sites are suitable, then the following environmental factors should be considered in final site selection:

a. Minimize disturbance to fish and wildlife habitats. For example, if sufficient gravel deposits are available elsewhere, active or high-water channels and vegetated habitats should be avoided.

b. Minimize disturbance to local visual and scenic quality. For example, locate sites in areas away from public view or where they will be least visible; insofar as possible select locations that will allow one to preserve the character of the area.

c. Bed load replenishment rate should be considered in site selection if the life span of the site is to cover several consecutive years, even if there will be inactive periods. Glacial and mountain origin rivers, particularly near headwaters, have potentially higher replenishment rates than rivers originating in foothills or coastal plains.

d. Projects requiring large gravel quantities (roughly 50,000 m^3 or more), should consider the following:

- Scraping of unvegetated, mid-channel bars and lateral bars in braided rivers, and medium and large split channel rivers. This recommendation should be followed as long as suitable buffers (see Section V A 3 and Appendix A) can be maintained.

- Pit excavation in terraces or inactive floodplains, as long as sufficient buffer is maintained between the pit and the active floodplain

e. Projects requiring less than 50,000 m^3 should consider:

- Scraping unvegetated mid-channel and lateral bars in braided rivers and large and medium split channel rivers; this recommendation should be followed as long as suitable buffers can be maintained

- Scraping point bars of large and medium meandering rivers

- Scraping in terraces or inactive floodplains

C. VERIFICATION OF SITE ACCEPTABILITY

Before proceeding with SITE PLANNING, review the selected site on the basis of the entire Guidelines Manual. Give special attention to the

SITE PREPARATION and SITE OPERATION sections. The matrix tables within SITE OPERATION specifically present recommendations about gravel deposit type and location, and mining method.

The purpose of this verification review is to minimize decision-making delays resulting from failure to consider site specific features.

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Site Planning
Section II

Site planning should incorporate the SITE PREPARATION, SITE OPERATION, and SITE CLOSURE guidelines presented in Sections V, VI, and VII.

A. GENERAL GUIDELINES

1. If the technical method of gravel removal has not been determined during site selection, then either scraping, pit excavation, dredging or a combination can be chosen by reviewing the SITE OPERATION guidelines

2. Design of the specific work area boundaries should incorporate the following factors:

   a. Site configurations should avoid use of long straight lines and be shaped to blend with physical features and surroundings (Figure 2):

      - Scraping point bars of meandering and sinuous systems to maintain slopes and contours resembling those of the natural bars

      - Scraping mid-channel and lateral bars of braided systems, to maintain natural gravel bar shapes

      - Excavating pits to provide irregular shorelines with curved configurations, islands, spits, and diverse shoreline depths

   b. Vegetated areas should not be disturbed when sufficient quantities of gravel can be obtained within prescribed buffers in unvegetated areas of floodplains (buffers guidelines are in Section V A 3 and Appendix A)

c. When vegetated areas cannot be avoided, it is usually desirable to locate material sites in large stands of homogeneous mature vegetated areas.

d. The site should be located on the same side of the floodplain as the material use point. This will minimize the need for crossing of active channels.

3. All work scheduling should attempt to avoid conflicts with sensitive biological events and extreme hydrological events.

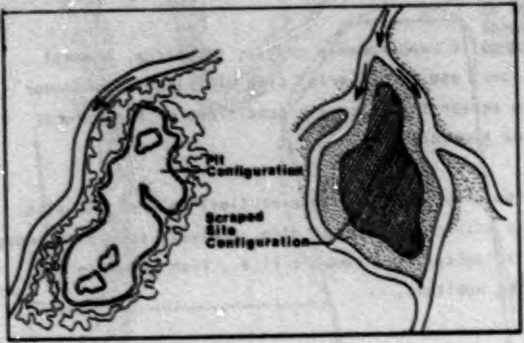

Figure 2. Examples of desirable material site locations and configurations.

a. In general, work should be scheduled to avoid peak biological events, such as local fish migration and spawning, and bird and mammal breeding, nesting, and rearing-of-young. For example, site clearing of vegetation should occur in fall to avoid the sensitive spring and early summer avian nesting season. Occasions may occur when gravel removal operations should be suspended to avoid disturbance to an essential biological event.

b. Where site work is occurring in the active or inactive floodplain, scheduling should allow for work suspension and removal of equipment, materials, and stockpiles from the floodplain during spring breakup or other predictable flood events

4. After incorporating the conclusions from the four levels of decisions from Section I into a final site selection, a site investigation (described in Appendix B) should be conducted to:

   a. Verify that the candidate site can produce the quantity and quality of desired gravel

   b. Collect hydraulic measurements such as discharge, channel cross sections, and bed material size distribution whenever possible to assess the hydraulic conditions of the natural channel (see Appendix B).

   c. Determine the presence or absence of limiting fish and wildlife habitat within the project site. Analysis should be based on annual biological requirements (i.e., fish spawning and overwintering habitat).

   d. Flag site boundaries and buffer locations in preparation for an agency site inspection. Flagging should be highly visible, of weather resistant material, and maintained through site operation and closure.

      - Mark site boundaries on mature trees in timbered areas with some highly visible material (such as paint or cloth material).

      - For flagging in the open-water season use 1-m metal stakes or rods driven approximately 0.5 m into the ground with a red flag of approximately 15 x 15 cm attached

- At sites to be opened during winter, all work area locations (such as active channels, buffer locations, vegetated areas, and gravel deposits) should be surveyed from reference points established during the initial open-water site visit (Figure 3). Reference points should be selected so they can be found in heavy snow cover during future site preparation. Establishment of these surveys will reduce accidental damage to active channels and buffer zones.

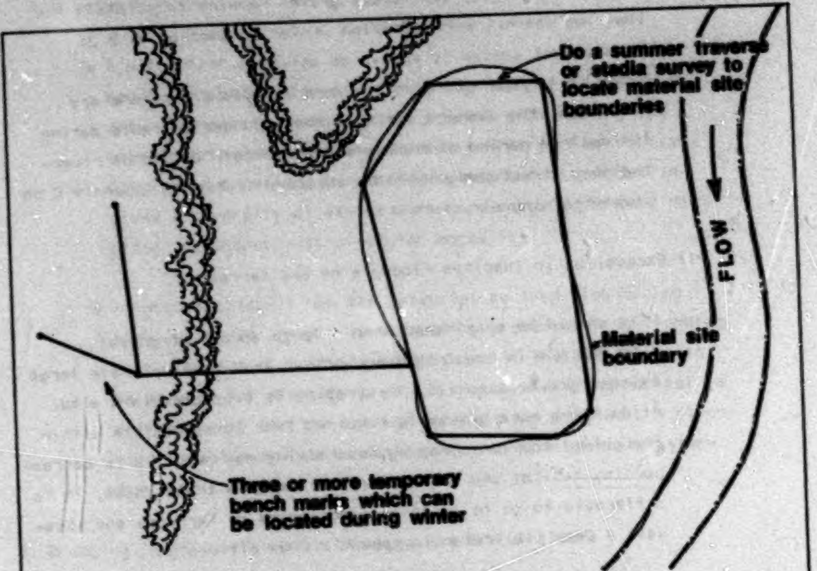
Do a summer traverse or stadia survey to locate material site boundaries
FLOW
Material site boundary
Three or more temporary bench marks which can be located during winter

Figure 3. Schematic diagram showing recommended survey at sites which are to be opened during winter.

5. If winter active-channel mining is contemplated, an additional site visit should be conducted during winter. This visit is to determine the presence of water at or downstream from the proposed site.

B. SPECIFIC GUIDELINES

Specific site planning should proceed based upon the selected gravel removal method.

1. Scraping in Active and Inactive Floodplains:

   a. Material sites should be mined to ensure that after the material is removed, sufficient gravel remains to maintain the low-flow channel configuration (refer to Section VI B 2)

   b. Since it is most efficient to work scraped sites in a dry condition, the average depth of the groundwater table during the desired period of mining and the effective use of river-training structures should be assessed (refer to Appendix C on river-training structures)

2. Pit Excavation in Inactive Floodplains and Terraces:

   a. Pits should be considered when a large amount of gravel (>50,000 m^3) is required from a river that does not have large exposed gravel deposits. If scraping is conducted in a situation where more gravel is required than is accessible within the guidelines for scraping, overmining may result with corresponding habitat and channel alterations. In these cases, it is preferable to go to inactive floodplains or terraces and excavate a deep pit (refer to Appendix D on pit design).

   b. Pits should be located in areas where they will have a low probability of diverting channels into the mined area. This means they should be located on terraces, inactive floodplains, or stable islands with the recommended buffer. Terraces are preferred because of the reduced probability of channel diversion.

c. It is usually desirable to locate the pit within a dominant, homogeneous mature vegetative community. This location will reduce the chance that a terrestrial habitat of limited availability will be affected and will generally increase habitat diversity.

d. It should be decided during site planning whether or not the pit is to be connected to the river following the mining operation

- A pit outlet provides an avenue of escape for fish that become trapped in the pit during high water. A connected pit, if properly designed, can provide fish rearing and overwintering and increase the availability of sport fish. Conditions necessary to provide suitable fish habitat include a diversity of depths with an average depth that minimizes the probability of winter mortality.

- An unconnected pit has the potential to trap fish during high water. If the pit is adequately protected from flooding with a buffer of suitable height, and if the pit is not to be managed for fish the creation of overwintering habitat is not necessary and the average depth is not critical. A diversity of water depths is desirable to create adequate waterfowl and shorebird habitat.

3. Dredging in Active Channels of Large and Medium Rivers

a. Dredging in active channels of large and medium rivers should be considered only if suitable floodplain sites are unavailable outside the active channel. In this situation, nonfloodplain sources also should be evaluated.

b. Sites located in active channels should consider the following:

i) Essential aquatic habitat in and downstream from the site

ii) Unimpeded instream migrations

iii) Maintenance of natural pool:riffle ratio; riffles should be avoided except in the following situations:

- In a long riffle, excavation may be acceptable near the middle of the riffle
- When more rapid site recovery is desirable
- When the riffle is unproductive aquatic habitat because of cementation or infiltration by fine sediments
- Where deepening the thalweg may reduce or eliminate aufeis development

Work Plan Development
Section III

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Work Plan Development
Section III

Detailed work plans should be prepared and submitted as part of the application to the appropriate review agency. Work plans should include detailed sketches, ground photographs, topographic maps, and if available, aerial photographs showing:

- Accurate site boundaries
- Individual sequential work areas and boundaries
- Buffer locations and boundaries for both individual work areas and the total site
- Locations of all floodplain temporary and permanent structures planned for site operation and closure (e.g., access roads, river-training structures, bank protection devices, stockpiles, washing and processing structures, and overburden piles)
- Locations of gravel-use points (such as access roads, airstrips, and camp pads)

Visual resource classification maps, if available from State or Federal agencies, of the region surrounding the work site, should also be submitted. Specific sections of the work plan should present written descriptions that address the following topics.

A. A brief legal project description identifying:

1. Names and addresses of applicant and major contractors, if known

2. Intended material use, location of material use, and anticipated life of the project utilizing the material

3. Life of the material site

4. Ownership of material site and adjacent lands

B. A technical site description identifying:

1. Size and specific location of all individual and cumulative work areas

2. Season, duration, and frequency of all site work by individual work area

3. Buffer locations, dimensions, type of vegetation, and soil description

4. Methods, schedules, and locations for vegetative and overburden clearing, temporary storage and handling, and permanent disposal

5. Quantity, type, and use of material to be removed from each work area

6. Method of gravel removal in each work area, including type and number of equipment and identification of each material handling step to be performed within the material site (i.e., collection, stockpiling, sorting, washing, processing, transporting). Locations and operation of each handling step should also be identified. Washing operation descriptions should identify silt control procedures and processing operations should identify use and storage locations of materials such as solid waste and cement-processing additives.

7. Cross-sectional configuration and location of progressive working elevations by season or major project scheduling periods. For

example, if the site is to be worked over several years, the designed profile and configuration during each spring breakup and low summer flow should be identified. Final working profile and configuration and site closure profile and configuration should also be identified.

8. Specific locations, specifications, material composition, and construction method of access roads, river-training structures, and silt control structures.

9. Site closure (rehabilitation) methods and procedures including locations and specifications of permanent structures (such as overburden piles). At pit sites consideration should be given to whether access should remain after site closure. This decision influences the design life of the access road.

10. Descriptions of logistical support and material transportation methods, general routes, and frequency to and from the material site

C. An environmental description of the project area identifying:

   1. Known biological resources of the general vicinity, including fishery resources of the subject river system

   2. Timing of major fish and wildlife history events and presence of limiting habitat occurring in the vicinity of the material site

   3. Hydraulic characteristics (such as channel configuration and discharges) in the vicinity of the material site

D. The approved work plan should be considered an integral part of the project by both the permittee and the permitting and monitoring agencies

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Agency Review
Section IV

A. The proposed material site location and accompanying work plan should be reviewed by appropriate agencies to evaluate the compatibility of the project with the environment. This review should consider disapproval or modification of the work plan if the material site directly affects areas or species of special concern. Examples of such areas or species include:

1. Threatened or endangered species and their habitats that are deemed essential to the survival or recovery of these species that are recognized by Federal and State governments. A current listing of species and information as to their distribution may be obtained from the U.S. Fish and Wildlife Service or the State Fish and Game agency. Sites affecting these species or their habitats may be prohibited, or require substantial justification.

2. Habitats limiting local populations (such as fish spawning and overwintering habitats, Dall sheep lambing areas or raptor nesting habitats). Sites directly affecting these habitats should not be considered further unless alternate sites are not available.

3. Undercut vegetated banks and associated riparian zones

4. Incised vegetated banks and associated riparian zones, except for properly utilized access by fill ramps

5. Springs

6. Active channels in small rivers of meandering, sinuous, and straight configurations

7. Wetlands - The primary criteria most frequently used in wetland definitions include presence of water-saturated soil conditions, and vegetative communities adapted to such conditions. For current definition, delineation and jurisdiction refer to local offices of the U.S. Army Corps of Engineers.

8. Other Federal, State, and private lands with special use and regulation such as wilderness areas, parks, wildlife refuges, archaeological areas, and historical landmarks

B. A field inspection of the proposed site by the appropriate agency should take place prior to site approval. A field inspection as described in Appendix B should occur during an open-water season and include an evaluation of:

1. Overall technical feasibility of project as detailed in the work plan

2. Overall quality of fish and wildlife habitat to be disturbed

3. Presence of any previously unknown features identified in Section IV-A

4. Hydraulic characteristics such as discharge and stage in the vicinity of the material site

Alternative sites should be requested of the applicant if it is judged in this review that the material site will alter areas or species of special concern to the point that population survival is affected.

C. A second inspection by the appropriate agency should occur during site operation to:

1. Confirm that the work plan is being followed

2. Determine if unexpected biological, hydraulic, or engineering characteristics warrant a deviation from the original work plan

D. A third field inspection by the appropriate agency should occur in the latter stages of site closure prior to site abandonment and removal of essential site closure equipment to ensure:

1. Final slopes, contours, and configurations of the work area comply with the intent of the work plan

2. All additional site closure work has been performed and the site will be abandoned, within practical limits, as close to original conditions as possible

Additional visits after closure may be appropriate (i.e., to monitor erosion control).

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Site Preparation
Section V

A. GENERAL GUIDELINES

1. At sites opened during winter all work area boundaries established during the initial site visit (such as active channels, buffer locations, vegetated areas, gravel deposits) should be verified to avoid accidental damage to active channels, buffer zones, and vegetated banks

2. Design of floodplain access should incorporate the following factors:

   a. Minimize access through vegetated habitats

   b. If necessary to traverse vegetated areas:

      - During winter do not remove the organic layer and do not cover the access route with gravel; use ice roads to avoid compaction of organic layers

      - During summer do not remove the organic layer, but protect from mechanical ripping and tearing by covering with gravel

   c. Floodplain access should occur at the inside of a meander to avoid trafficing incised banks at outside meanders

   d. Avoid crossing other incised floodplain banks

   e. When a bank crossing is required it should be protected with a gravel fill ramp

   f. Avoid crossing active channels

g. When required, active channels should be crossed via temporary bridges, low-water crossings, or properly culverted access road. Refer to Appendix E on fish passage.

h. Floodplain travel to and from the work area should occur only on designated access roads

3. Buffers are areas of undisturbed ground surface that are designed to maintain the integrity of active channels. In general, low-flow or flood-flow buffers are recommended at a site. Low-flow buffers are recommended for scraping operations on unvegetated gravel bars adjacent to active channels. Flood-flow buffers should be used for scraping or pit-mining operations that are separated from active channels. Operators of gravel removal activities may desire to use buffers wider or higher than those recommended in order to protect the site from inundation while it is being worked, since water levels at the time of mining may exceed those for which the buffer is designed.

   a. The low-flow buffer is a strip of undisturbed ground surface extending up the bank and beneath the water surface from the low summer flow water's edge (Figure 4). Its purposes are:

      - To maintain the integrity of the channel configuration and
      - To minimize change to the aquatic habitat

      The boundaries of the low-flow buffer are defined as follows (Figure 5):

      1) The upper limit at any location along the channel is that point on the bank that is the lesser of the following:

         - having an elevation that is 0.5 m above the low summer flow water surface elevation

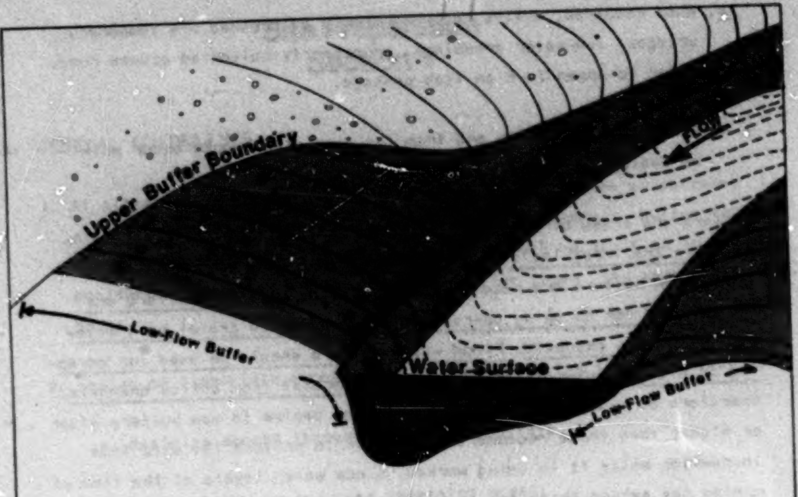

Upper Buffer Boundary
Flow
Low-Flow Buffer
Water Surface
Low-Flow Buffer

Figure 4. Schematic diagram of the low-flow buffer.

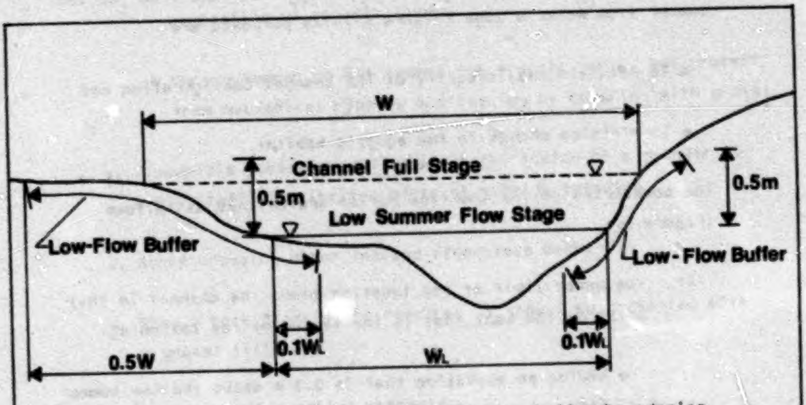

W
Channel Full Stage
0.5m
Low Summer Flow Stage
0.5m
Low-Flow Buffer
Low-Flow Buffer
0.1WL
0.1WL
0.5W
WL

Figure 5. Schematic diagram showing low-flow buffer boundaries.

- having a horizontal distance to the low summer flow water's edge which is equal to one-half the channel top width at channel-full flow conditions

iii) The lower limit at any location along the channel is that point on the bed that has a horizontal distance to the water's edge which is 10 percent of the top width of the low summer flow channel.

b. The flood-flow buffer is a zone of usually undisturbed floodplain, often vegetated, separating the material site from the active channel(s) (Figure 6). Its purpose is to prevent the

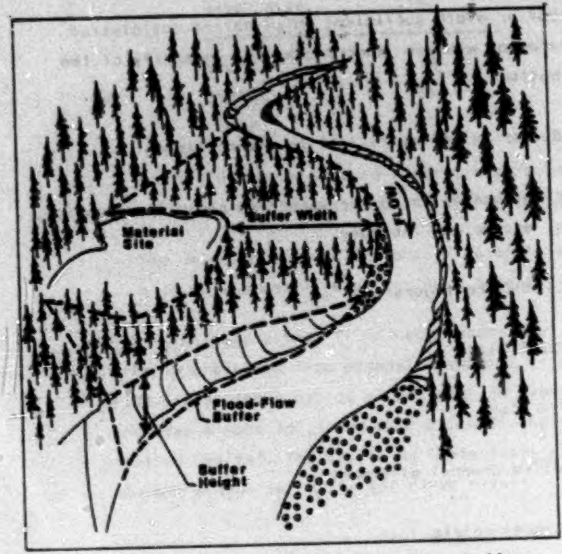

Buffer Width
Material Site
FLOW
Flood-Flow Buffer
Buffer Height

Figure 6. Schematic diagram of the flood-flow buffer.

active channel(s) from diverting through the material site for a selected period of time. Although it is preferable to use natural vegetated buffers, man-made buffers in the form of river-training structures and bank protection devices (see Appendix C) may be necessary where natural buffers do not exist or are too low to be effective.

i) Flood-flow buffer design, as discussed in Appendix A, should include consideration of:

- Buffer location with respect to the active channel(s) and the material site
- Buffer width sufficient to withstand anticipated erosion without jeopardizing the integrity of the buffer
- Buffer height sufficient to divert floods

ii) Important variables to the selection of buffer location, width, and height include:

- Channel configuration
- River size
- Hydrology
- Active channel alignment
- Channel aufeis
- Permafrost or ice-rich banks
- Type of vegetation

- Soil composition

iii) Recommended flood-flow buffer designs are listed below for scrape and pit gravel removal operations:

- Scrape - In these sites, it is recommended that the site be protected from channel diversion by a buffer for at least 5 to 8 years. This allows the vegetation to become re-established. The following Table lists recommended minimum buffer widths for different river sizes:

River size	Minimum width (m)
Small	15
Medium	35
Large	50

  - The width can be reduced to half the recommended minimum at the downstream end of the scraped site
  - The height of the buffer should be at least as high as the water level during a 5-year flood

- Pit - In these sites, it is recommended that the site be protected from channel diversion by a flood-flow buffer for a period of at least 20 years. This provides a more long-term protection of the newly created habitat. The following Table lists recommended minimum widths for different river sizes:

River size	Minimum width (m)
Small	75
Medium	150
Large	250

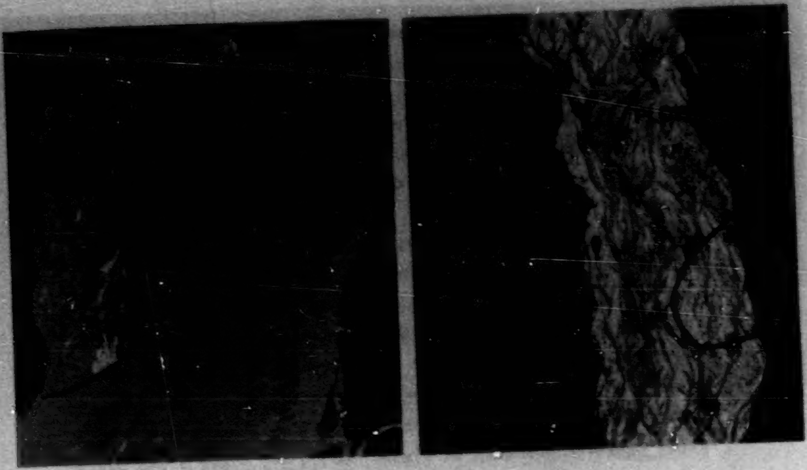
- The width can be reduced to 20 percent of the recommended minimum at the downstream end of the pit

- The height of the buffer should be at least as high as the water level during a 20-year flood

iv) Flood-flow buffers should be designed on a site-specific basis following the guidelines presented in Appendix A under any of the following conditions:

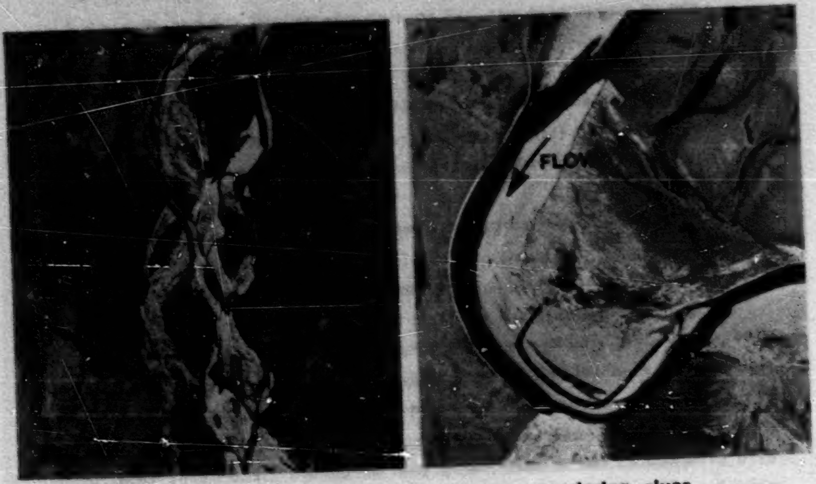
- The material site is on a very large river (e.g., Yukon River, Kuskokwim River, Tanana River, and Colville River)
- The available space does not allow for a buffer of recommended width
- Buffer height is lower than the recommended design height
- The active channel is angled into the bank at an angle greater than about 30 degrees
- Channel aufeis occurs in the river adjacent to the site
- Banks consist of primarily sands, are sparsely vegetated, or are ice-rich permafrost material
- Evidence of active bank erosion is found during the site visit

4. Temporary dikes should be constructed around the site if the site will be inundated during operation (Figure 7). Refer to Appendix C discussing river-training structures.



a. Very large braided river

b. Medium braided river



c. Medium split river

d. Large meandering river

Figure 7. Potential locations of temporary dikes constructed around sites having the potential to flood during site operation.

a. These structures should be constructed to minimize disturbance to low-flow channels

b. Dikes should be constructed of on-site gravel materials

c. Fish entrapment should be avoided at all times

5. In cases where vegetated areas cannot be avoided, clearing should proceed using the following guidelines:

   a. If possible, sites containing dense vegetative cover should be cleared during periods that do not coincide with periods of bird and mammal breeding, nesting, and rearing-of-young. In most cases fall would be the most desirable period for vegetation removal.

   b. When mature timber must be cut, it should be salvaged for private or commercial use. If no such use exists, timber should be either:

      - Stockpiled out of the active floodplain

      - Used in site rehabilitation of adjacent material sites

      - Hauled to designated disposal areas

      - Piled and burned in accordance with appropriate regulations

6. Other vegetation and organic overburden can be mechanically cleared and should be collected. This material should be saved for possible use during site closure. At sites located in inactive floodplains or terraces, this material should be broadcast over the surface during site closure. In sites located only in an active floodplain, this material can be piled (not broadcast) within the site according to the following recommendations. The presence of this material in the materi-

al site in an acceptable manner will facilitate more rapid vegetative recovery and subsequent fauna recovery.

a. If the site occurs only within an inactive floodplain or terrace in any configuration or size river, the material should be temporarily stored either:

   - In piles within or on the edge of the material site

   - In a temporary storage area outside the material site (such as an approved disposal area, material site, or unvegetated inactive floodplain)

b. If the site occurs only within an active floodplain, vegetative slash and organic overburden should be disposed of based upon river configuration:

   i) If located in a braided river this material should not be piled or broadcast in the active floodplain of these systems

   ii) If located in a meandering, sinuous, split, or straight river this material can be handled as follows:

      - If sufficient space exists away from the active channel, store this material in piles within the material site. On-site storage should occur at a location that reduces repeated handling. During storage the material can be stockpiled in as small an area as possible to reduce excessive site enlargement to compensate for covered gravel. These materials should be stockpiled in a location and in such a manner that slope failures and erosion would not endanger the adjacent stream or have other adverse effects. These piles should be:

- Located away from active channels

- Long and narrow

- Orientated parallel to the flow

- Of sufficient height to be above the 2-year flood

- Armored on the active channel side to prevent erosion

Refer to Figure 8.

- If insufficient space exists within the mined area away from active channels this material may be stored in:

  - An approved disposal area

  - An upland area

  - Other material sites

  - Unvegetated inactive floodplains

7. Settling ponds are recommended if the materials are to be washed within the material site. Ponds should be protected with dikes designed for the 10-year flood. Ponds generally should be located as far from the active channel as possible. See Appendix F for guidelines to be considered in the design of settling ponds.

B. SPECIFIC GUIDELINES FOR SCRAPED SITES

1. Material sites worked during the open-water season should be protected from flows corresponding to at least the 2-year recurrence

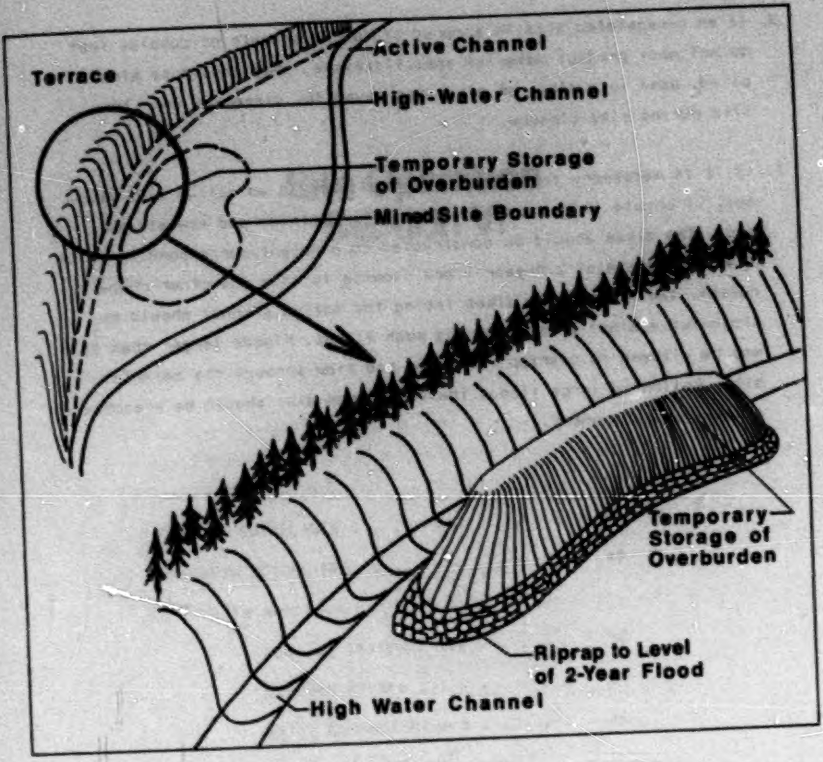

Terrace
Active Channel
High-Water Channel
Temporary Storage of Overburden
Mined Site Boundary
Temporary Storage of Overburden
Riprap to Level of 2-Year Flood
High Water Channel

Figure 8. Typical view of temporary storage of overburden showing desirable location, shape, and armor protection.

interval flood by dikes designed to withstand such floods without erosion. These dikes should not encroach on the low-flow buffer. The purpose of the dikes is to reduce the probability that flow will pass through the active site, thus reducing the potential for introducing high concentrations of fine sediments into flows that are incapable of transporting them to normal dispositional areas.

2. If an unvegetated site is armored by coarse gravels or cobbles that do not meet project material specifications, they should be stockpiled, used in a dike, or otherwise saved for dispersal over the site during site closure.

3. If it is necessary to locate a material site in an active side channel, it should first be diked off at the upstream and downstream ends. The dikes should be constructed to a height corresponding to at least the stage of a 5-year flood flowing in only the other channel(s). The side of the dikes facing the active channel should be protected against erosion during such floods. Floods larger than this may be allowed to overtop the dikes and flow through the material site. Following large floods the downstream dike should be breached to allow fish escapement.

Site Operation
Section VI

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Site Operation
Section VI

A. GENERAL GUIDELINES

1. Changing the course of any active channel should be avoided

2. All gravel removal operations should be conducted in a clean and efficient environmentally acceptable manner. For example:

   a. All fuels and toxic materials should be stored out of the floodplain

   b. Avoid fueling and servicing equipment within the active floodplain to reduce spills and disposal of materials (e.g., used crankcase oil and lubricants)

   c. The by-products from support operations occurring at the material site (such as gray water, domestic sewage and solid waste) should be disposed of in an approved fashion (consult current Federal and State regulations). In general these by-products should not be discarded within the active or inactive floodplains without proper treatment.

3. Floodplain access and travel should occur only as designated in the approved work plan

4. Buffer zones should not be disturbed in any manner that would reduce their function. For example:

   a. Vegetative structure, width, and banks of flood-flow buffers should not be altered

   b. Heavy equipment should not repeatedly traffic low-flow buffers, or reduce their height or configuration

5. The approved work plan should be followed. If unexpected conditions are encountered in the field, operators should:

   a. Immediately notify the appropriate agency of the encountered situation, and anticipated work deviation

   b. Proceed in a manner that closely follows this manual until the permitting agency responds

6. Gravel washing operations within the floodplain, settling pond use, and washing activities should be conducted per the general recommendations provided in Appendix F. In general:

   a. Where gravel washing operations are required, the wash water should be recycled with no effluent discharge to the active floodplain

   b. If settling ponds are required, they should be designed to provide adequate retention time for site-specific conditions. The outflow structure should be perched to avoid fish entrapment.

   c. The use of a flocculant may be necessary to meet the Federal-State effluent standards

B. SPECIFIC GUIDELINES

Specific guidelines for site operation have been developed for rivers of different configuration and size, and for different gravel deposit locations in each configuration and size. The proposed site should be closely matched with the following matrix Tables which direct attention to specific guidelines applying to scraped, pit excavated, and dredged sites.

This section is organized in four parts, as follows: Page

1. Use of Guidelines Matrices 50

Special Instructions 50

Guidelines Based on River Type

Braided Rivers - Matrix 1, with general guidelines statements 57

Split Channel Rivers - Matrix 2, with general guidelines statements 60

Meandering, Sinuous, and Straight Rivers - Matrix 3, with general guidelines statements 63

Specific Guidelines Based on Mining Method

2. Scraped Sites 65

3. Pit Excavated Sites 70

4. Dredged Sites 74

1. Use of Guidelines Matrices

SPECIAL INSTRUCTIONS

River Configuration

Each of the three matrices is designed for a specific river configuration. The guidelines for one river configuration are not identical to those for another configuration, thus the user must be careful that the proper matrix for the river in question is being used. The configurations represented by the three matrices are:

- Braided Rivers (Matrix 1)

- Split Channel River (Matrix 2)

- Meandering, Sinuous, and Straight Rivers (Matrix 3)

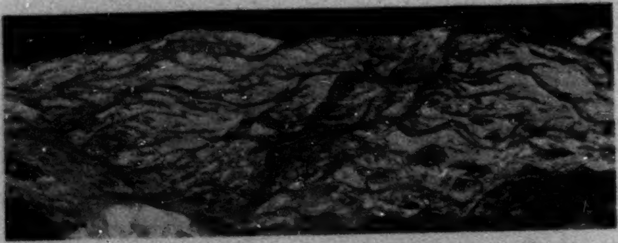
Braided Rivers. A braided river typically contains two or more interconnecting channels separated by unvegetated gravel bars or vegetated islands (Figure 9a). Its floodplain is typically wide and sparsely vegetated, and contains numerous high-water channels. Bars separating the channels are usually low, gravel surfaced, and easily eroded.

Split Channel Rivers. A split channel river has numerous stable islands which divide the flow into two channels (Figure 9b). There are usually no more than two channels at a given reach and other reaches are single channel. The banks of the channel(s) are typically vegetated and stable. The split river floodplain is typically narrow relative to the channel width.

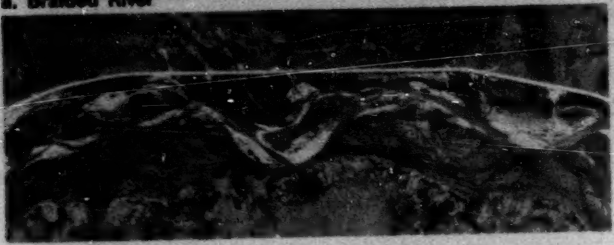
Meandering, Sinuous, and Straight Rivers. Meandering and sinuous rivers (Figures 9c and 9d) have a single channel that winds back and forth within the floodplain; straight rivers wind less. Very few islands are found in these systems. Point bars and lateral bars are common, with point bars more frequent in meandering rivers and lateral bars in straight rivers. Banks on the outside of a bend in a meandering river are normally unstable whereas the banks of a straight river are relatively stable. The floodplains of meandering and sinuous rivers are usually as wide as the meander belt, and therefore, are narrower for sinuous rivers than for meandering rivers. Floodplains of straight rivers are narrow.

Template Preparation

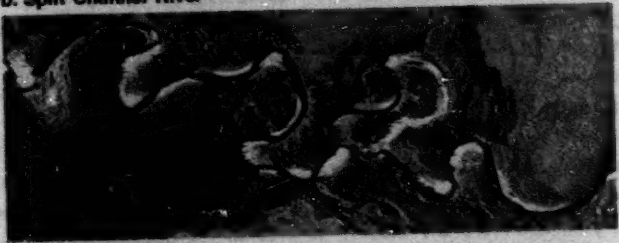
Required Data. After the proper matrix has been identified, the template describing the work plan can be prepared. A template can either be prepared by: (1) using the blank template provided in the back of this manual, or (2) aligning a blank sheet of paper under the parameter descriptions of one of the



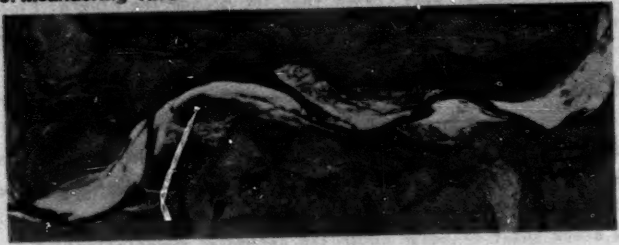
a. Braided River



b. Split Channel River



c. Meandering River



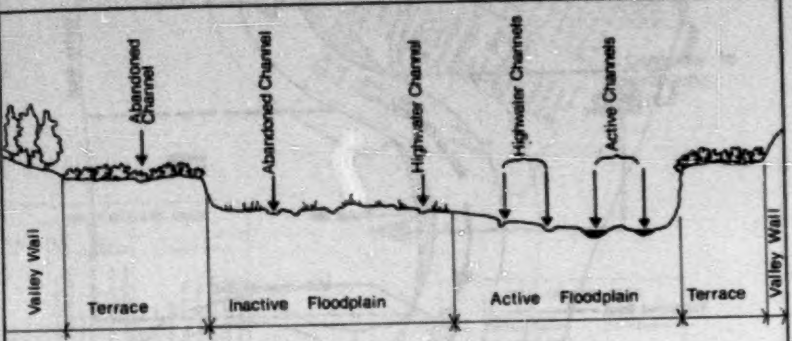
d. Sinuous River

Figure 9. Examples of river configurations (straight rivers are similar to sinuous but with a lower sinuosity ratio).

matrices, drawing lines on the blank sheet to correspond to those of the heading columns and identifying each parameter in its proper position. An example of a template will be shown later (Figure 12a). To fill out the template the following information is required:

- The size of the river at which the mining operation will be conducted (small, medium, or large)

- The site location or locations with respect to floodplain type (active, inactive, terrace) (see Figure 10)



Abandoned Channel
Abandoned Channel
Highwater Channel
Highwater Channels
Active Channels
Valley Wall
Terrace
Inactive Floodplain
Active Floodplain
Terrace
Valley Wall

Figure 10. Floodplain location types.

- The type of channel or channels associated with the desired gravel deposit (active, high-water, abandoned) (see Figure 11)

- The type of gravel deposits to be mined (see Figure 11)

Filling Out a Template. For each individual template evaluation, only one river size, site location, and associated channel can be used. Any number of deposit types can be used as long as they are all associated with the same floodplain and channel type being considered.

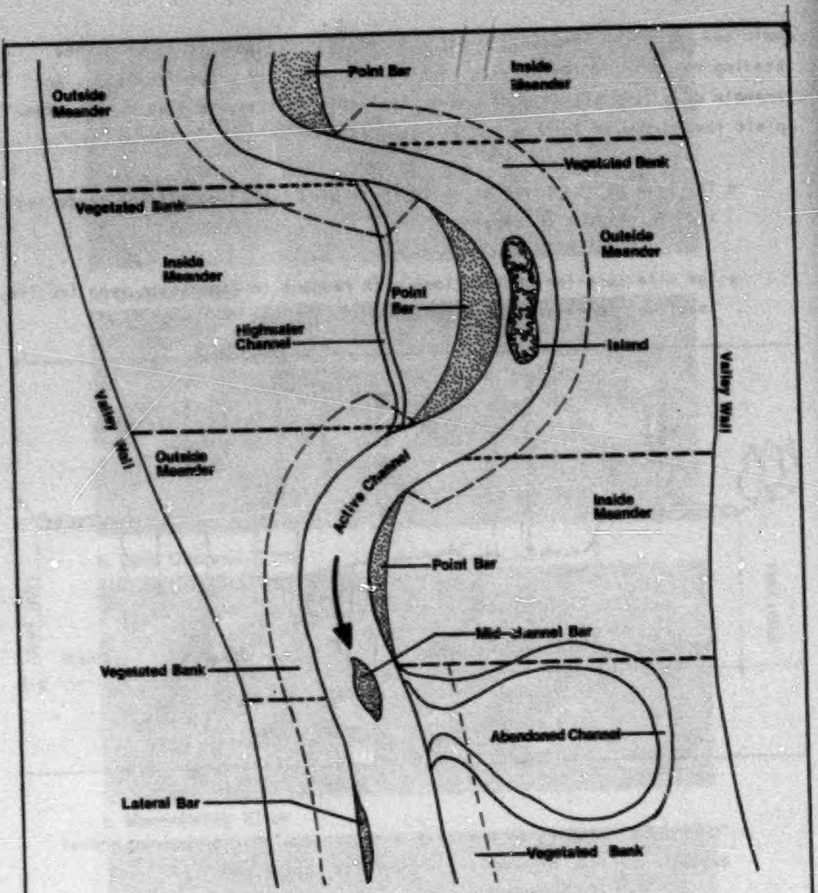
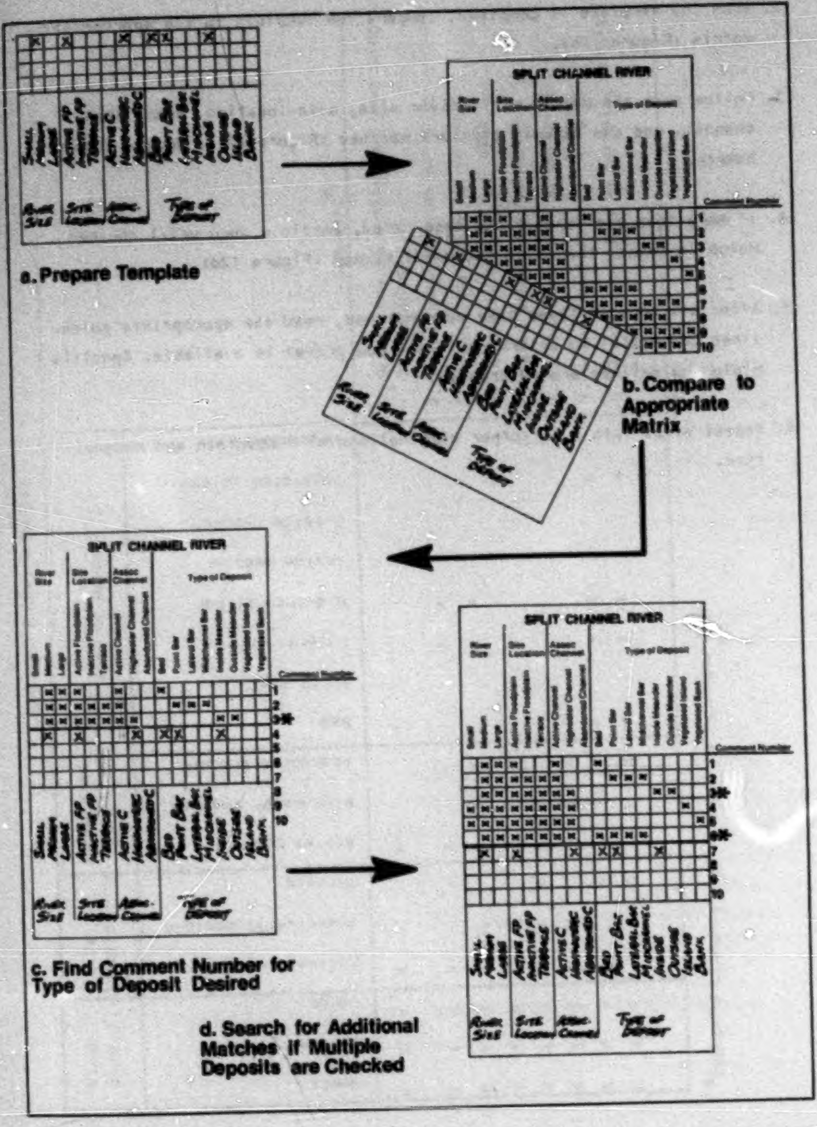

Point Bar
Inside Meander
Outside Meander
Vegetated Bank
Vegetated Bank
Outside Meander
Inside Meander
Point Bar
Highwater Channel
Island
Valley Wall
Valley Wall
Outside Meander
Active Channel
Inside Meander
Point Bar
Mid-Channel Bar
Vegetated Bank
Abandoned Channel
Lateral Bar
Vegetated Bank

Figure 11. Types of deposit

1. Place an "X" under the template space which corresponds to the individual parameter being considered (Figure 12a).


SPLIT CHANNEL RIVER
River Size
Site Location
Assoc. Channel
Type of Deposit
Comment Number
1
2
3
4
5
6
7
8
9
10
River Size
Site Location
Assoc. Channel
Type of Deposit

a. Prepare Template

b. Compare to Appropriate Matrix

c. Find Comment Number for Type of Deposit Desired

d. Search for Additional Matches if Multiple Deposits are Checked

Figure 12. Example of how the completed template is matched to determine availability of gravel.

2. When the template is complete, compare the template to the appropriate matrix (Figure 12b).

3. Follow down the matrix until river size, site location, associated channel, and one deposit type are matched (Figure 12c). Record Comment Number.

4. If more than one deposit has been "X"ed, continue down until another match is found, then record Comment Number (Figure 12d).

5. After all deposit types have been matched, read the appropriate guidelines Comment(s) to determine if and how gravel is available. Specific mining guidelines are referenced.

6. Repeat steps 1 to 5 for other combinations of floodplain and channel type.

BRAIDED RIVERS - MATRIX I

River size			Site location			Associated channel			Type of deposit								Comments[a]
Small	Medium	Large	Active floodplain	Inactive floodplain	Terrace	Active channel	High-water channel	Abandoned channel	Bed	Point bar	Lateral bar	Mid-channel bar	Inside meander	Outside meander	Vegetated island	Vegetated bank	
X	X	X	X			X			X								1. Gravel may be available by scraping or dredging.
X	X	X	X			X					X	X					2. Gravel available by scraping.
X	X	X	X	X			X	X			X	X					3. Gravel available by scraping.
X	X	X	X	X		X	X	X							X		4. Generally should not be mined.
X	X	X	X	X	X	X	X									X	5. Banks should not be mined.
X	X	X	X	X			X	X	X								6. Gravel available by scraping.
X	X	X			X		X		X		X	X			X		7. Gravel available by scraping.
X	X	X		X	X			X	X		X	X			X	X	8. Gravel available by scraping or pit mining.

[a] Expanded comments begin on following page.

Expanded Comments for Braided Rivers

Comment 1. Generally, the bed of an active channel should not be disturbed. If bed deposits are the only available source, the gravel should be taken only under strict work plans and stipulations.

- It is recommended that side channel(s) be mined rather than the main channel. Select side channel(s) that carry less than approximately one third of the total flow during the mining period; block off upstream ends and mine by scraping operations. Refer to Scraping Guidelines (VI B 2).
- If the main channel must be mined, dredging may be an appropriate method. Refer to Dredging Guidelines (VI B 4).

Comment 2. Gravel is available by scraping gravel deposits to near the low summer flow, maintaining appropriate buffers, or no lower than the water level present during the mining operation. Refer to Scraping Guidelines (VI B 2).

Comment 3. Gravel is available by scraping such that the configuration of the channel is not greatly changed and there is not a high probability of channel diversion through the mined area. Refer to Scraping Guidelines (VI B 2).

Comment 4. Vegetated islands are often a limited habitat in these systems and should generally be excluded from the work plan. Exposed deposits should be considered before vegetated island deposits. If deposits in feasible alternative locations are not sufficient, and vegetated islands are abundant in the particular reach in question, up to about 10 to 20 percent of this habitat may be removed from about a given 5-km length of the floodplain. Refer to Scraping Guidelines (VI B 2) or Pit Guidelines (VI B 3).

Comment 5. Vegetated river banks of both active and high-water channels should not be disturbed because of biological and hydraulic alterations. These should be removed from work plans.

Comment 6. Gravel is available by scraping within the channel, but the general configuration of the channel should be maintained. Refer to Scraping Guidelines (VI B 2).

Comment 7. In these systems it is recommended to scrape exposed deposits in the active floodplain. If sufficient gravel is not available in the preferred deposits, gravel may be available by scraping in these locations, but the general configuration of the channel should be maintained. Refer to Scraping Guidelines (VI B 2).

Comment 8. In these systems it is recommended to scrape exposed deposits in the active floodplain. If sufficient gravel is not available in the preferred deposits, gravel is available in these locations by either pit or scrape methods. Generally, pits should only be considered when more than 50,000 m^3 are required. Refer to Scraping Guidelines (VI B 2) and Pit Guidelines (VI B 3).

SPLIT CHANNEL RIVERS - MATRIX 2

River size			Site location			Associated channel			Type of deposit								Comments[a]
Small	Medium	Large	Active floodplain	Inactive floodplain	Terrace	Active channel	High-water channel	Abandoned channel	Bed	Point bar	Lateral bar	Mid-channel bar	Inside meander	Outside meander	Vegetated island	Vegetated bank	
	X	X	X			X			X								1. Gravel may be available by scraping or dredging.
	X	X	X			X				X	X	X					2. Gravel available by scraping.
	X	X	X	X	X	X	X						X	X			3. Some gravel may be available by scraping or pit.
X	X	X	X	X	X	X	X								X		4. Generally should not be mined.
X	X	X	X	X	X	X	X									X	5. Banks should not be mined.
	X	X	X	X	X		X		X	X	X	X					6. Gravel available by scraping.
X			X			X			X	X	X	X	X	X	X		7. Should not be mined.
X			X	X	X		X		X	X	X	X	X	X			8. Generally avoid, not much available.
X	X	X		X	X			X	X	X	X	X	X	X	X	X	9. Gravel available by scrape or pit.
	X	X			X		X		X	X	X	X	X	X	X		10. Gravel available by scraping.

---

[a] Expanded comments begin on following page.

Expanded Comments for Split Rivers

Comment 1. Generally the bed of an active channel should not be disturbed. If bed deposits are the only available source, the gravel should be taken by dredging or scraping under strict work plans and stipulations.

- It is recommended that side channel(s) be mined rather than the main channel. If the site contains a side channel that caries less than approximately one third of the total flow during the mining period this channel can be blocked at its upstream end and mined by scraping. Refer to Scraping Guidelines (VI B 2).

- If channels approximating this size are not available then either the side or main channel can be mined using dredging. Refer to Dredging Guidelines (VI B 4).

Comment 2. Gravel is available by scraping deposits to near the low summer flow, maintaining appropriate buffers, or no lower than the water level present during the mining operation. Refer to Scraping Guidelines (VI B 2).

Comment 3. Gravel is available if suitable buffers are maintained to protect against channel diversion. Refer to Scraping Guidelines (VI B 2), Pit Excavation Guidelines (VI B 3), and Buffer Recommendations (V A 3 and Appendix A).

Comment 4. Vegetated islands are often a limited habitat in these systems and often control channel integrity. Exposed deposits should be considered before vegetated island deposits. If deposits in feasible alternative locations are not sufficient, and vegetated islands are abundant in the river system in question, about 10 to 20 percent of this habitat may be removed from about a 5-km reach of floodplain. Refer to Scraping Guidelines (VI B 2) and Pit Guidelines (VI B 3).

Comment 5. Vegetated river banks of both active and high-water channels should not be disturbed because of biological and hydraulic alterations. These areas should be removed from work plans.

Comment 6. Gravel is available by scraping in the high-water channel, but precautions must be taken to avoid channel diversion. Refer to Scraping Guidelines (VI B 2).

Comment 7. Mining is not recommended in or near the active channel of small split channel rivers because there is not much material available.

Comment 8. There generally is not much material available in these deposits and they should be avoided. If only a small amount (<10,000 m^3) of gravel is needed, these deposits may be considered for scraping. Refer to Scraping Guidelines (IV B 2).

Comment 9. Gravel is available by either pit or scrape methods. Generally these should be considered for large amounts of gravel that are not present in adequate amounts in exposed deposits. Pits should be considered when more than 50,000 m^3 are required. Refer to Scraping Guidelines (VI B 2) and Pit Guidelines (VI B 3).

Comment 10. Some gravel is available by scraping, but the general configuration of the channel should be maintained. Refer to Scraping Guidelines (VI B 2).

MEANDERING, SINUOUS, AND STRAIGHT RIVERS - MATRIX 3

River size			Site location			Associated channel			Type of deposit								Comments[a]
Small	Medium	Large	Active floodplain	Inactive floodplain	Terrace	Active channel	High-water channel	Abandoned channel	Bed	Point bar	Lateral bar	Mid-channel bar	Inside meander	Outside Meander	Vegetated island	Vegetated bank	
	X	X	X			X			X								1. Some gravel may be available by dredging.
	X	X	X			X				X	X	X					2. Gravel available by scraping.
	X	X	X	X	X	X	X						X	X			3. Some gravel may be available.
X	X	X	X	X	X	X	X								X		4. Not recommended in these systems.
X	X	X	X	X	X	X	X									X	5. Banks should not be mined.
	X	X	X	X	X		X		X	X	X	X					6. Gravel available by scraping.
X			X	X	X	X	X		X	X	X	X	X	X			7. Should not be mined.
X				X				X	X	X	X	X	X	X		X	8. Generally avoid, not much available.
X	X	X		X	X			X	X	X	X	X	X	X	X	X	9. Gravel available by pit or scrape.

[a] Expanded comments begin on the following page.

Expanded Comments for Meandering, Sinuous, and Straight Rivers

Comment 1. Generally the bed of an active channel should not be disturbed. If bed deposits are the only available source, the gravel should be taken by dredging only under strict work plans and stipulations. Refer to Dredging Guidelines (VI B 4).

Comment 2. Gravel is available by scraping deposits to near the low summer flow, maintaining appropriate buffers, or no lower than the water level present during the mining operation. Refer to Scraping Guidelines (VI B 2).

Comment 3. Gravel is available if suitable buffers are maintained to protect against channel diversion. Refer to Scraping Guidelines (VI B 2), Pit Guidelines (VI B 3), and Buffer Recommendations (V A 3 and Appendix A).

Comment 4. Vegetated islands are rare in these river systems and should not be disturbed. It is recommended they be removed from the work plan.

Comment 5. Vegetated river banks of both active and high-water channels should not be disturbed because of biological and hydraulic alterations. These areas should be removed from the work plan.

Comment 6. Gravel is available by scraping in the high-water channel, but precautions must be taken to avoid channel diversion. Refer to Scraping Guidelines (VI B 2).

Comment 7. Mining in the active or high-water channels of these small rivers is not recommended because there is not much material available.

Comment 8. There generally is not much gravel available in these deposits and they should be avoided. If only a small amount (<10,000 m^3) of gravel is needed, scraping may be considered. Refer to Scraping Guidelines (VI B-2).

Comment 9. Gravel is available by either pit or scrape methods. Generally these areas should be considered for large amounts of gravel that are not present in adequate amounts in exposed deposits. Pits should be considered when more than 50,000 m^3 are required. Refer to Scraping Guidelines (VI B 2) and Pit Guidelines (VI B 3).

2. Specific Guidelines for Scraped Sites

a. Gravel bars adjacent to high-water and abandoned channels can be scraped to a specified level at the edge of the channel and should be sloped toward the channel to provide proper drainage. An average maximum depth should be maintained in the channel to provide for flow containment during periods of low flow within the channel. The average maximum depth at any point along the channel is the distance between the average thalweg profile line and the channel-full stage at that point (Figure 13).

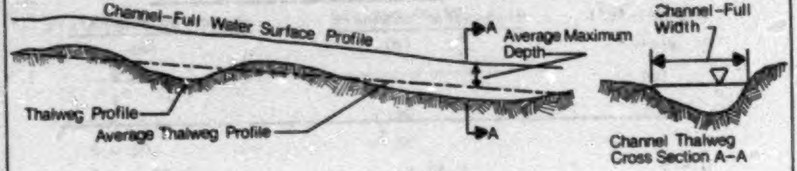

Channel-Full Water Surface Profile
A
Average Maximum Depth
Channel-Full Width
Thalweg Profile
Average Thalweg Profile
A
Channel Thalweg Cross Section A-A

Figure 13. Definition of average maximum depth and channel-full width in a channel.

Recommended values of maximum depth that should be maintained in the channel are listed below for three ranges of channel-full width. Values of half the recommended depths should be considered minimum depths below which flow containment would be ineffective.

Braided Configuration

Channel-full width (m)	Recommended maximum depth (m) High-water channels	Abandoned channels
0 - 5	0.30	0.05
5 - 30	0.50	0.15
30 or greater	0.80	0.50

Split, Meandering, Sinuous, and Straight Configurations

Channel-full width (m)	Recommended maximum depth (m) High-water channels	Abandoned channels
0 - 5	0.40	0.15
5 - 30	0.60	0.30
30 or greater	1.00	0.60

b. Gravel bars adjacent to active channels can be scraped to a specified minimum level and should be sloped toward the channel to provide proper drainage. The purpose of a minimum level is to minimize hydraulic change to the active channel at low flows. The recommended minimum level of gravel removal is controlled by the highest of the following three levels:

- The upper level of the low-flow buffer. This is defined in Site Preparation Guidelines (V A 3a)

- The level corresponding to 0.15 m above the average water level expected during the gravel removal operation

- The level that will maintain a specified average maximum depth in the channel (Figure 13). Recommended values and minimum values of maximum depth that should be maintained are listed below for three channel width ranges at channel-full flow. Values of half the recommended depths should be considered minimum depths below which hydraulic change is more likely to occur.

Braided Configuration

Channel-full width (m)	Recommended maximum depth (m)
0 - 5	0.30
5 - 30	0.50
30 or greater	1.00

Split, Meandering, Sinuous, and Straight Configurations

Channel-full width (m)	Recommended maximum depth (m)
0 - 5	0.50
5 - 30	1.00
30 or greater	1.30

c. Scraping in high-water and abandoned channels should follow the alignment of the channel. Gravel removal design depends on several factors listed below:

- Side slopes should be stable for expected flow conditions during a 2-year recurrence interval flood. This will reduce the potential for rapid channel shifting.
- Channel-full top width should not be increased if it can be avoided. If additional material is needed that cannot be obtained from other dry channels or unvegetated bars, the channel being worked can be widened to a width no greater than that of the active channel and preferably half that of the active channel (especially on meandering, sinuous, and straight rivers).
- Longitudinal channel slope into the material site should not exceed 10 times the average slope of the channel (Figure 14). This will minimize the potential for extensive upstream bed degradation. The upstream end of the section of increased slope should be a sufficient distance from the nearest active channel to minimize the potential for channel diversion.

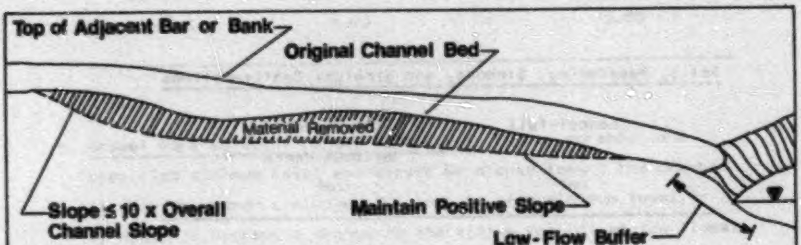

Top of Adjacent Bar or Bank
Original Channel Bed
Material Removed
Slope ≤ 10 x Overall Channel Slope
Maintain Positive Slope
Low-Flow Buffer

Figure 14. Sketch of high-water or abandoned channel longitudinal profile showing recommended channel bed slopes resulting from scraping the channel bed.

- Longitudinal channel slope out of the material site at the downstream end should not be adverse (bed elevation increasing in the downstream direction). Adverse slopes cause ponding and potential fish entrapment. Maintaining a positive slope (bed elevation decreasing in the downstream direction) is recommended to allow for channel drainage during a flood recession. The downstream end of the disturbance should be separated from the nearest active channel by at least the width of the low-flow buffer for that channel (Figure 14).

d. Scraping in active side channels that have been diked and dewatered should follow the alignment of the channel and should stay between the low-flow buffers. Gravel removal design depends on other related factors listed below.

- Side slopes should be stable for expected flow conditions during a 5-year recurrence interval flood. This will minimize the potential for slope failure and subsequent deterioration of the low-flow buffer.

- The width of excavation is limited by the limits of the low-flow buffers (Figure 15). The bottom width is limited only by the equipment used.

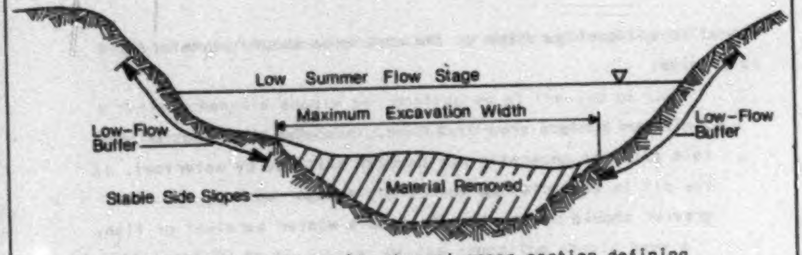


Figure 15. Sketch of active side channel cross section defining excavation limitations.

- Channel slope into and out of the material site should be stable under all flow conditions up to and including a 5-year flood. This will minimize the potential for bed degradation.

- The existing pool-riffle sequence should be retained during the gravel removal operation. If it is disturbed, a similar sequence should be restored following the operation.

- Active channels scheduled for winter scraping should be evaluated for the presence of flowing water in and downstream from the site; if water is present, the site should not be mined.

e. Mining of high-water or abandoned channel bed and associated bars should follow Guidelines VI B 2c and VI B 2a, in that order, if sufficient gravel quantities are not available from only one of these sources. If sufficient gravel quantities are still not available and channels are not abundant, or if high-water or abandoned channels are not available, it may be necessary to form new well-defined channels following Guideline VI B 2c. High-water channels formed during the gravel mining operation should have an alignment similar to that of natural high-water channels or the active channel(s) of the river.

3. Specific Guidelines for Pit-Excavated Sites

A profile and configuration of the work area should be maintained to provide:

a. A minimum surface area of 2.0 ha. Inundated pits smaller than this size are generally not heavily utilized by waterfowl. If the pit is connected to the river, a mean depth of 2.5 m or greater should be provided to insure winter survival of fish.

b. A relatively long and narrow shape aligned longitudinally in the floodplain and providing an irregular configuration with islands and peninsulas is preferable (Figure 16a and 16b)

- Islands and low peninsulas provide more diverse shoreline and aquatic habitats

- If the river does divert through the pit, it will have an alignment to follow and will more quickly develop into a channel configuration

c. An outlet channel for a path of low resistance when the pit is inundated, reducing erosion of undisturbed terrestrial habitat. An outlet channel also provides an avenue of escape for fish which may become trapped during high flows.

- Outlet channels should be deep enough to allow fish passage during low flow conditions and be as narrow as possible

- All outlet channels should be on the downstream end of the pit to prevent premature degradation of the stream channel and pit

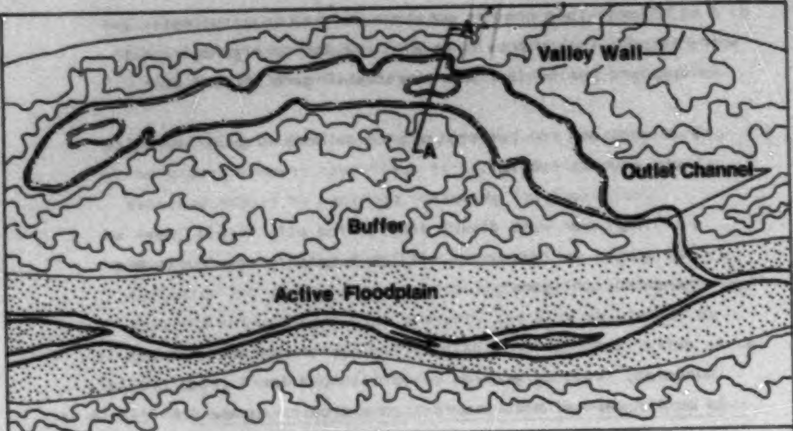
- Outlet channels should be connected to a non-depositional area of an active channel and be angled downstream

- Outlet channels should not be of straight line configuration

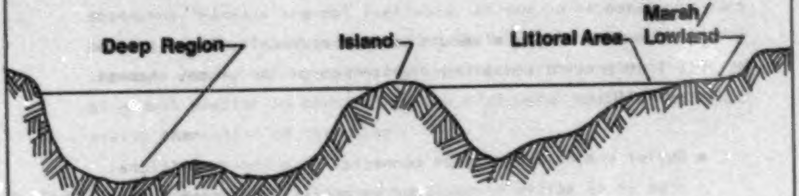
- Outlet channels should be constructed at the end of the site closure to minimize siltation in the river

d. A diversity of water depths and bank slope

- At least 30 to 50 percent of the shoreline should have a gradual slope to provide areas for emergent aquatic vegeta-


A'
Valley Wall
A
Outlet Channel
Buffer
Active Floodplain

a. Aerial view of an acceptable pit configuration.


Marsh/
Lowland
Deep Region
Island
Littoral Area

b. Side view of an acceptable depth regime (Section A-A).

Figure 16. Example of a preferred shape and depth profile of gravel pits in floodplain terraces and connected to the active channel.

tion, shorebird and waterfowl feeding, juvenile fish rearing, and muskrat habitat (Figure 16b). The gradual slope of these areas should allow a natural transition of vegetative communities and provide exposed mud flats or the potential for future marsh habitat development.

- The remaining shoreline should be more steeply sloped to provide habitat more beneficial to other groups such as diving ducks, geese, swans, beaver, and adult fish
- As mentioned above, a mean depth of 2.5 m or greater of combined littoral and deep areas should be provided if there is an outlet channel or if a non-connected pit is to be managed for fish. For example, 25 percent littoral area averaging 0.5 m and 75 percent deep area averaging 3.2 m yields an overall mean depth of 2.5 m. Refer to the Pit Design Appendix D.
- In a pit not connected to the active channel, and not to be managed for fish, a similar shape and depth configuration is appropriate, but a mean depth of 2.5 m is not required. These pits should be protected with an adequate buffer from flooding so that fish entrapment is minimized. In this case, the main purpose is the creation of shorebird and waterfowl habitat.
- If there is a choice between mining to a shallow depth over a broad surface area or deep over a restricted surface area, the choice should be to increase depth before increasing area. This minimizes terrestrial disturbance and reduces the probability of fish winter mortality.

4. Specific Guidelines for Dredged Sites

a. Active channels scheduled for winter dredging should be evaluated for the presence of flowing water in and downstream from the site; if water is found, the site should not be mined

b. Depth of excavation in an active channel should be limited by the width of the low summer flow channel minus the low-flow buffer; the side slopes should be designed to remain stable during 5-year flood flows

c. The length of excavation in a pool of the active main channel should not exceed the length of the pool. If a riffle is to be mined, the length of excavation should not exceed the average length of the pools within 5 km up and downstream of the site.

d. The bed slopes at the upstream and downstream ends of the active channel excavation should be designed to remain stable during 5-year flood flows to minimize the potential for degradation

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Site Closure
Section VII

A. GENERAL GUIDELINES

After mining is completed, material sites should be rehabilitated to return them, as closely as is possible, to pre-mining condition.

1. The site should be sloped and contoured immediately following completion of operations. In cases where sites consist of two or more aliquots, each should be sloped and contoured as completed. Any seeding and fertilizing should be done in spring or summer.

2. The work area should be shaped and contoured to minimize ponding and to blend with surrounding features and topography

3. Access roads, culverts, and bridges should be removed (unless otherwise approved) and the areas restored. Fill ramps at incised banks should also be removed and the bank stabilized (if damaged) to minimize subsequent erosion.

4. All manmade debris should be removed from the site

5. All cut slopes encountered during gravel removal or access road construction should be stabilized to prevent thermal, fluvial, and wind erosion

6. Dewater settling ponds of the clear surface water either by pumping or lowering dikes. Silt may be:

   - Left in place in inactive floodplains and terrace locations; protective structures should be lowered to a level corresponding to the level of the impounded silt

- Broadcast or piled with other overburden and vegetative slash and debris (refer to guideline VII A 7)

- Removed from active floodplain sites to approved disposal areas

7. In general, at sites that were previously vegetated and will contain nonflooded areas following site operation, rehabilitation should facilitate natural revegetation and site recovery. When organic overburden and vegetative slash and debris are available, it is recommended that natural revegetation be favored over artificial seeding and fertilization. Final placement of overburden and vegetative slash and debris should incorporate the following guidelines.

a. Active floodplains

i) In braided systems it is unlikely that any overburden or vegetative slash and debris will be available. However, if available it should not be piled within the active floodplain.

ii) In meandering, sinuous, split, and straight systems this material may be piled within the active floodplain. The design and loction of these piles should incorporate the following (Figure 17). They should be:

  - Located away from active channels and in areas where they are subjected to the least hydraulic erosion

  - Long and narrow in configuration (about 15-20 m long and 3-5 m wide, where possible)

  - Orientated parallel to the flow

  - About 1 m above the 2-year recurrence flood at its top

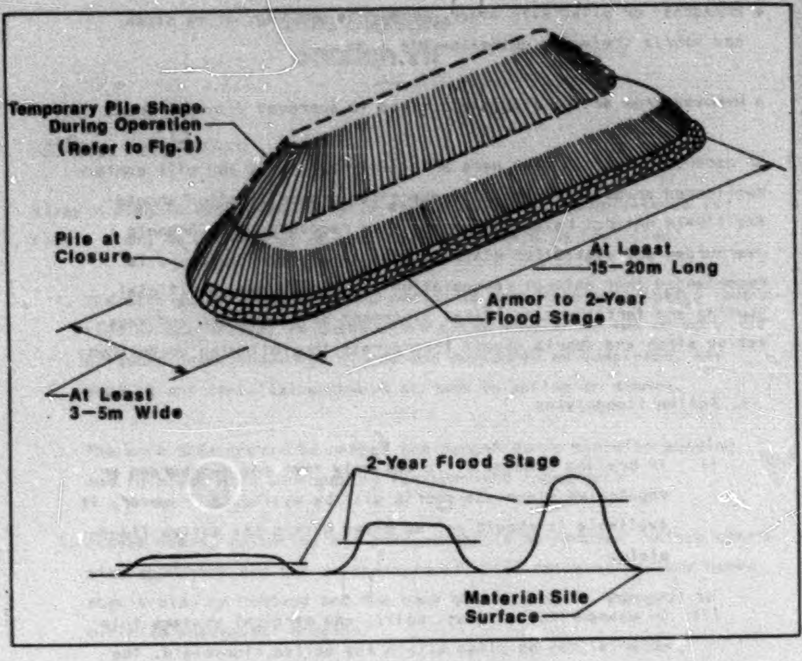
Temporary Pile Shape
During Operation
(Refer to Fig.8)
Pile at
Closure
At Least
15—20m Long
Armor to 2-Year
Flood Stage
At Least
3—5m Wide
2-Year Flood Stage
Material Site
Surface

Figure 17. Typical view of desirable shape and configuration, relative to 2-year flood levels, of permanently placed overburden piles.

- Armored on the active side to prevent erosion (refer to discussions of bank protection in Appendix C)

- Piled to maximize surface area, provided this meets the above criteria

If sufficient material exists, it is desirable to produce several piles distributed throughout the mined area. If insufficient material exists to meet the above criteria, it should not be piled within the active floodplain. If insufficient space exists within the mined area away from the active channel, this material may be used either in site rehabilitation of adjacent material sites or disposed of in approved upland areas.

iii) Neither artificial seeding nor fertilization should be conducted in active floodplains

b. Inactive floodplains and terraces

At these locations in rivers of all configurations this material may be either piled or broadcast over the ground surface

i) At sites consisting only of inactive floodplains that are annually flooded it may be best to pile this material rather than broadcast it to reduce downstream transport. If piled, the guidelines presented above (7a) should be followed.

ii) At sites including terraces and inactive floodplains that are not annually flooded, this material should be broadcast throughout these portions of the mined site. In general, this material should be spread about 10 cm deep and should cover as large an area as possible.

iii) If this material is not available for use in site rehabilitation of terraces and inactive floodplains, artificial seeding and fertilization may be considered and should follow current state-of-the-art techniques for arctic and subarctic regions

B. SPECIFIC GUIDELINES

1. Specific Guidelines for Scraped Sites

a. Distribute coarse gravels or cobbles, when available, over the surface of the gravel removal area, to provide for a more rapid rearmoring of the surface

b. If the low-flow buffer was disturbed, return it to its natural configuration and height

c. At side channel sites which were diked to work in a dry condition, remove the downstream dike and lower the upstream dike to a level corresponding to the river stage of a 1.25-year flood. This will prevent large quantities of sediment from being washed from the site into the river at low-flow conditions.

2. Specific Guidelines for Pit Excavated Sites

a. Overburden and vegetated slash and debris should be:

- Broadcast or piled, or both, in the nonflooded portions of the mine site, including islands and shorelines
- If any material remains, some may be placed in the flooded portion of the site to provide nutrients and cover

b. Slope and contour shoreline banks and all overburden stockpiles in nonflooded portions of the mined area to provide naturally appearing configurations that blend with surrounding features. These procedures should provide and maintain those characteristics of diverse shoreline configurations and profile, bank slope, and water depth as discussed in previous operation guidelines.

c. Excess unused mined material should be used to form islands or vary water depths within the pit

d. Follow work plan regarding access to the pit

e. The outlet channel, if provided in work plan, should be constructed during the final phases of site closure. Refer to Operations Guidelines for design criteria (Section VI B 3c).

3. Specific Guidelines for Dredged Sites

If the low-flow buffer was disturbed, return it to its natural configuration and height

11

Appendices

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APPENDIX A

FLOOD-FLOW BUFFER DESIGN

INTRODUCTION

Flood-flow buffers should be designed to prevent the diversion of an active channel through the material site. The design life is usually some finite period ranging from 5 years for some scraped sites to possibly 50 years or more for some pit sites.

The recommended design procedure is to consider the lateral activity of the particular river based on its channel configuration and historical migration pattern. The river size, soil composition of the buffer material, vegetative cover, permafrost banks, and channel aufeis are also important considerations affecting the stability of the buffer. The hydrology of the river must be considered to evaluate the frequency that the buffer will be flooded. Each of these are discussed in more detail in the following sections.

BUFFER WIDTH

Lateral Channel Migration

The general procedure for estimating the amount of channel migration of a river is summarized in this section. The user is referred to Brice (1971) for a more detailed explanation of the procedure. Stereoplotters, when available, are a faster and more accurate means of estimating lateral migration. Additional information on stereoplotter use can be obtained from photogrammetry textbooks, photogrammetric consultants, or stereoplotter manufacturers' literature.

Because of the complexities of the bank erosion process, quantifying lateral migration usually involves the use of historical records. These are projected based on a knowledge of the channel configuration and other considerations discussed later. Aerial photographs are obtained of the reach of river being studied (generally at least two floodplain widths upstream and downstream from the mined site location). Photographic coverage is desired for as many years as are available, but should at least include photos 20 or more years apart for the evaluation of long-term changes. The photos can be reproduced to obtain slides as described by Brice (1971) or can be used in print form as described below:

1. Enlarge the photos to the same scale, whenever possible. Select three or more identifiable features on each photo. Place an overlay over one photo and mark the selected features on the overlay. Place the overlay over the other photo(s) and match the features to these marks to verify that the scale is the same. If the scales are identical, the river banks can be traced from each photo on the same overlay (Figure A-1). The lateral migration can be measured directly from the overlay. If the scales are not the same, the following steps are necessary.

2. Select two identifiable features on each of the photos and connect these to form a baseline (Figure A-2). These features should be located near the opposite ends of the photograph.

3. Subdivide the baseline into 10 or more segments and draw lines perpendicular to the baseline through each of the segment endpoints, extending the line through the area for which the lateral migration estimates are desired. Subdivide one of these lines and draw lines perpendicular to form a grid pattern (Figure A-3).

4. Prepare a similar grid to any desired scale on a sheet of paper. Transfer bank locations at each grid square boundary from each photo to the corresponding grid square boundary on the sheet of paper (Figure A-4). The rows and columns can be numbered and/or lettered to assist in the coordination of the transfer.

5. Connect the points on the paper to show the bank positions as they appear on the photos (Figure A-5). The smaller the grid is on the photos, the more accurate the bank lines will be. Lateral migration can be measured directly from this figure.

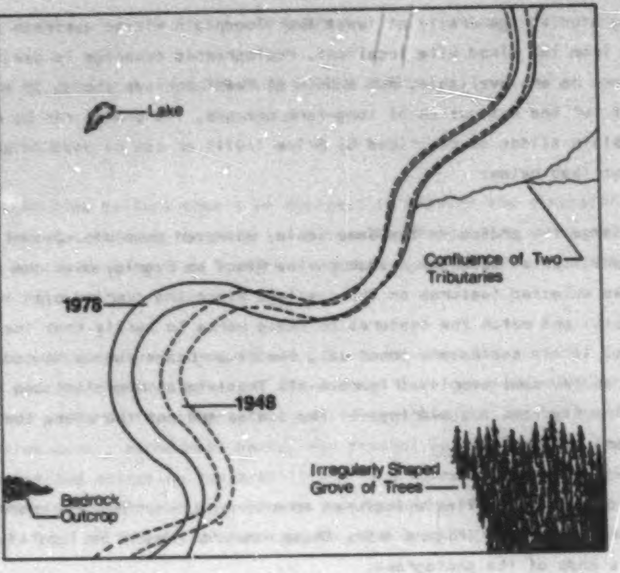

Lake
Confluence of Two Tributaries
1978
1948
Irregularly Shaped Grove of Trees
Bedrock Outcrop

Figure A-1. Schematic of overlay showing topographic features used as match points and bank lines from 1948 and 1978 photographs.

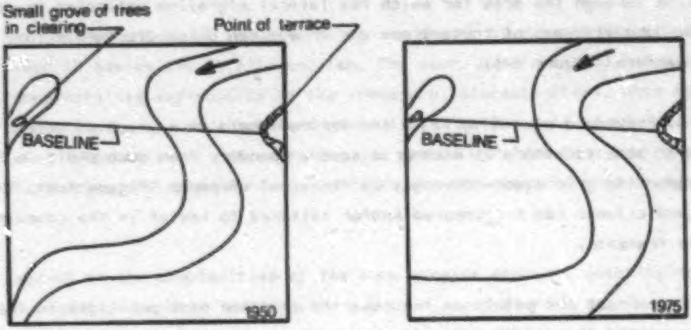

Small grove of trees in clearing
Point of terrace
BASELINE
BASELINE
1950
1975

Figure A-2. Schematic showing the selection of features to use as baseline endpoint for a portion of the study reach.

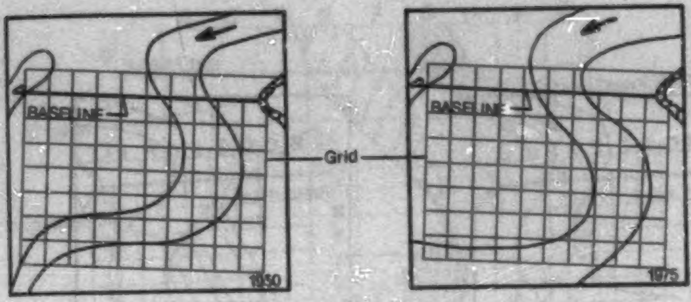


Figure A-3. Schematic showing the development of a grid on each photo.

The accuracy of this technique is sufficient for estimating the expected life of the buffer zone or, conversely, the required width of the buffer to meet the design life expectations. The accuracy of the average annual migration is greater for longer time periods between photo dates. Brice (1971) notes that the accuracy depends on the original scale and definition of the photos, the scale of the enlargement, the degree of scale distortion in the photo, the numbers and reliability of features used as reference points, and the care used in matching. It is generally not advisable to use the edge of lakes or rivers as reference match points or as bank lines for migration estimates because of the variability of this feature with water level changes.

Channel Configuration

Channel configuration is an important parameter in evaluating the potential for extending past records into the future. Each configuration is discussed separately in the following sections. The effects of buffer height are discussed in a different section.

Braided Configuration. Braided river channels are often very active laterally within the active floodplain. When a major active channel is flowing along a vegetated cut bank, substantial bank erosion can take place. If the major channel was flowing along the bank during the entire period over which

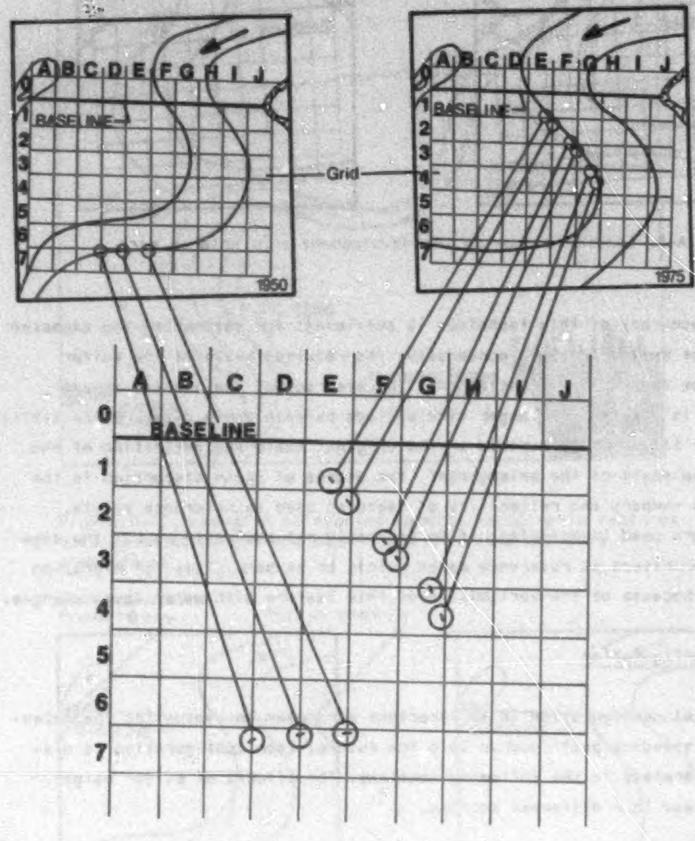

A B C D E F G H I J
0
1
2
3
4
5
6
7
BASELINE
Grid
1950
1975
A B C D E F G H I J
0
BASELINE
1
2
3
4
5
6
7

Figure A-4. Schematic showing the transfer of the bank lines from the photos to the paper grid.

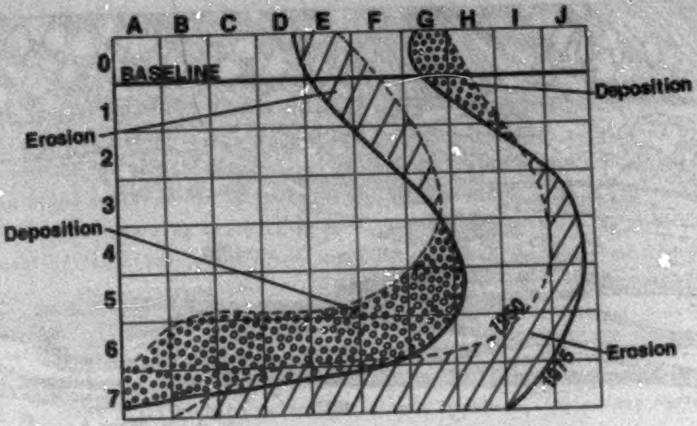


Figure A-5. Completed schematic showing bank lines and zones of erosion and deposition from which rates of erosion can be measured.

the historical migration rates were estimated, that migration rate may be projected into the future. Otherwise, different locations on the floodplains should be selected for obtaining estimates. Any change in the alignment of the channel should be accounted for, with erosion rates increasing for increasing angles of the channel to the bank. A factor of safety should be applied to the result, its value depending on the confidence one has in the estimate for a given system.

As a hypothetical example, consider the length of bank labeled A in Figure A-6. The dashed line shows the channel as it appeared in 1950 and the solid line represents the location of the 1975 river channel. Assume that the lateral migration of bank A was measured to be 100 m, or 4 m per year. Assume it is desired to have a buffer lasting at least 8 years to protect a scraped gravel removal area in the inactive floodplain. Projecting the past into the future results in 4 m per year for 8 years, or 32 m.

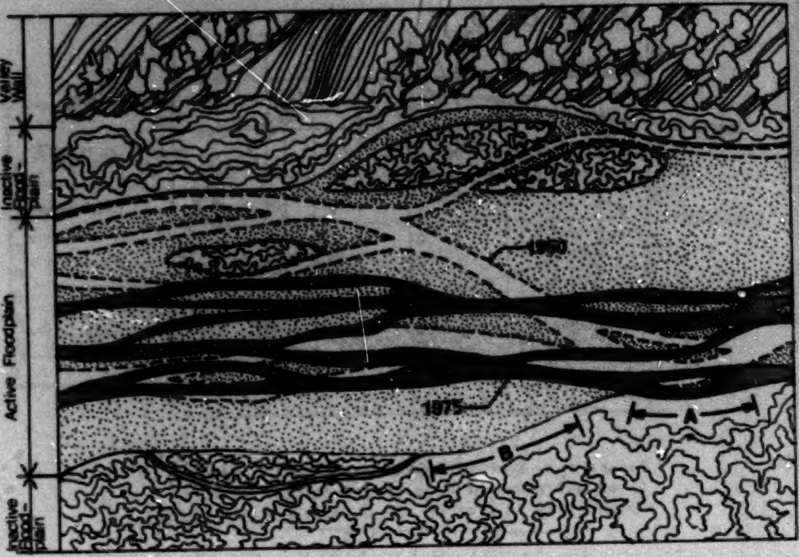


Figure A-6. Schematic of a river with a braided configuration with the 1950 and 1975 channel locations shown.

- The 1950 channel alignment was at a larger angle to the bank than the 1975 channel; thus it is likely that the erosion rates were greater than 4 m per year for the 1950 alignment and less than 4 m per year for the 1975 alignment. The 32 m can thus be reduced slightly, possibly to 28 m. If intermediate photos (between 1950 and 1975) are available, this figure can be substantiated by estimating the erosion rate for the more recent time period. If the year to year activity of the active channels is relatively low, it can be assumed that the potential for a significant change in alignment is low, and a fairly low safety factor can be used. In this case, a safety factor of 1.5 applied to the 28 m value would result in a buffer width of 42 m.

- If the active channels are known to change substantially every year, the reduction for alignment should not be applied and a safety factor

best copy available

of 2.0 or more could be used. This would result in a buffer width of 32 m x 2.0, or 64 m.

It is possible to find a braided configuration where the length of bank defining the buffer is not adjacent to an active channel, e.g., area B in Figure A-6. In this situation, the migration rate at area A can be applied to area B and modified for various considerations. Assuming an 8-year life is desired, the starting width is 32 m. This width can probably be reduced, the amount of reduction depending on the annual lateral activity level of the active channels. Assume that the activity level is low. One might reduce the number to 24 m in that situation. However, if the active channel does shift, it will likely impinge on the bank at a relatively large angle, increasing erosion potential. As a result, the width should be increased to 36 m instead of decreased to 24 m. With relatively stable channels, the safety factor can be about 1.5 to obtain a 54-m wide buffer.

Split Configuration. Rivers with split channel configurations are typically much more laterally stable than braided rivers. Thus, a historical record of erosion rates for a split river is fairly reliable for projecting future erosion rates. Channel alignment with respect to the buffer bank is an important consideration, with larger erosion rates expected from channels with larger angles to the bank. The factor of safety to apply to buffers on rivers with split configurations may be as low as 1.2; the factor of safety would increase with increasing channel activity and with decreasing confidence in the buffer width estimate. See discussions of meandering and braided configurations for hypothetical examples of extending historical erosion rates.

Meandering Configuration. Rivers with meandering configurations typically experience varying degrees of lateral migration, but the location and direction of migration is fairly predictable. A historical record of erosion rates for a meandering system can be used to predict future erosion rates with a high degree of reliability relative to previous configurations. Channel alignment with respect to an eroding bank tends to remain constant. The factor of safety to apply to the width of buffers on rivers with meandering configurations may be as low as 1.2 with a good data base; higher values should be used as uncertainty increases in estimating the erosion rate.

The pattern of a meandering river and the expected zones of erosion are illustrated in Figure A-7. Most meandering rivers deviate to some degree from

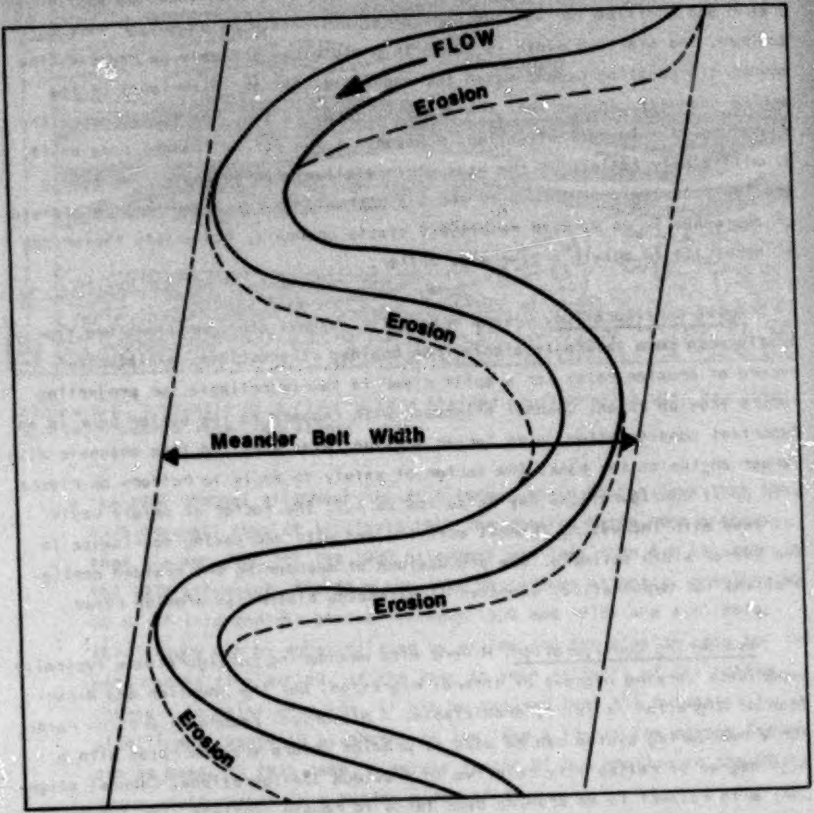

FLOW
Erosion
Erosion
Meander Belt Width
Erosion
Erosion

Figure A-7. Schematic of a meandering river showing the expected zones of erosion as the river meanders migrate down the valley.

this pattern, but the basic principles are the same. Meandering rivers exhibit a general tendency to migrate downvalley by eroding the cut bank on the outside of a bend from a point roughly midway through the bend and extending generally to the beginning of the inside of the next bend downstream. The gradual downvalley progression of the bends usually remains within a zone called the meander belt drawn near the outside of each meander. The width of the meander belt is usually constant for regular meander patterns. Irregular meander patterns do not necessarily maintain a constant meander belt width, but the erosion at the outside of bends is typical. The difference between a regular meander pattern and an irregular meander pattern and the expected zones of erosion associated with each is shown in Figure A-6. It is apparent

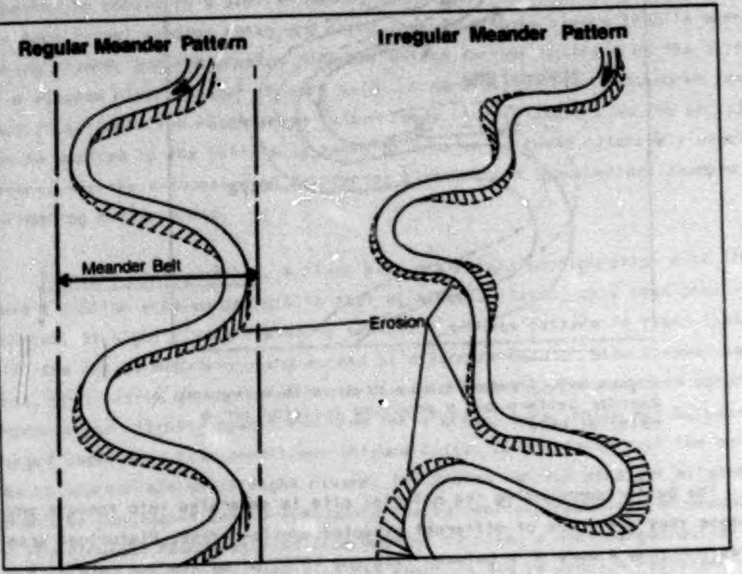


Figure A-6. Schematics of regular and irregular meander patterns and typical erosion zones.

from the location of the typical zones of erosion that the buffer width should generally be greater on the outsides of meanders and the upstream side of the insides of meanders.

As an example, consider the hypothetical river in Figure A-9 with a regular meander pattern. A material site is proposed on an inside meander of a small river, for which a buffer design life of 25 years is desired.

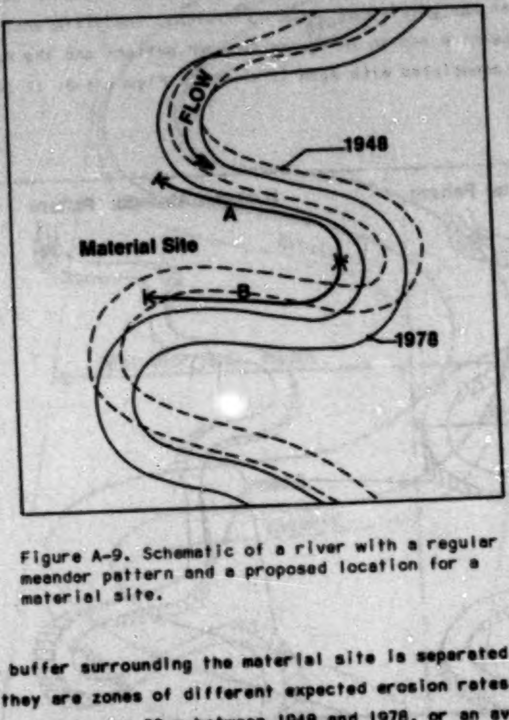


Figure A-9. Schematic of a river with a regular meander pattern and a proposed location for a material site.

The buffer surrounding the material site is separated into zones A and B because they are zones of different expected erosion rates. Historical erosion rates for zone A were 90 m between 1948 and 1978, or an average rate of 3 m per year. In zone B, 270 m of deposition has taken place during the same period. Starting with zone B, the bank opposite this zone should be investigated for any abnormality such as near-surface bedrock, which may stop the erosion of this bank. If there is such an abnormality, the buffer width should be increased from the standard minimum buffer width for the downstream end of the site given in Section V A 3b. In this example, assume no abnormality exists; use a standard minimum buffer width increased by 25 percent to account for the increased design life (25 years instead of 20 years) to derive a 19 m width in zone B. For zone A, an annual migration of 3 m per year over 25 years would prescribe a 75-m wide buffer. No change in the average erosion rate is expected from, for example, a meander cutoff developing upstream, and the historical period is longer than the design life, thus, the user can feel confident with the prediction. A safety factor of 1.2 can be used resulting in a recommended buffer width of 90 m.

Sinuous Configuration. A river with a sinuous channel configuration is expected to behave in a similar manner to that of the meandering rivers with a few exceptions: erosion rates are often less in sinuous rivers than in meandering rivers; and the erosion zone may extend farther upstream on the outside of a sinuous river meander (Figure A-10). Otherwise, similar procedures can be used to estimate the recommended buffer zones. Safety factors as low as 1.2 can be applied to the buffers in zones of erosion on these relatively stable rivers. See the discussion on meandering rivers for a hypothetical example of estimating buffer sizes.

Straight Configuration. A river with a straight configuration will likely have a similar erosion pattern to that of sinuous rivers, only less pronounced. Straight rivers typically exhibit a sinuous pattern in their thalweg with the inside meanders being formed by alternate bars or side channel bars. Thus, what little bank erosion takes place in a straight river would occur opposite and slightly downstream from these gravel bars, which may be submerged under most flow conditions (Figure A-11). Safety factors as low as 1.0 may be appropriate on straight rivers. The reason for the straight alignment should be considered before evaluating the buffer requirements. For example, if the straight reach resulted from meander cutoffs, a much larger buffer would be required than if the straight reach is due to erosion resistant banks.

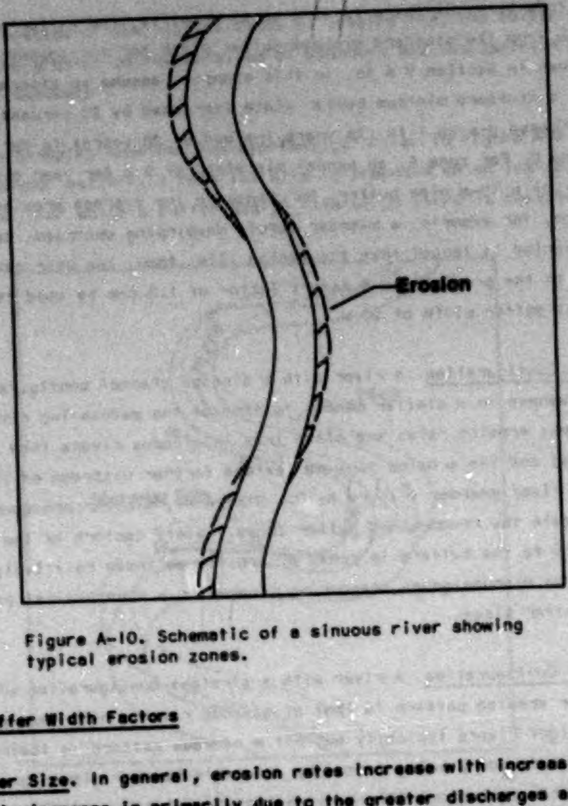


Figure A-10. Schematic of a sinuous river showing typical erosion zones.

Other Buffer Width Factors

River Size. In general, erosion rates increase with increasing river size. This increase is primarily due to the greater discharges associated with larger river size. The increase is also due to the wider valley floors filled with greater quantities of generally smaller sized alluvial sediments. The rate of increase of erosion rates with river size is difficult to quantify. If historical rates of lateral migration are available, river size does not have to be considered separately.

Soil Composition. The soil composition of the bank and buffer material is important to the erosion rate. Fine sands are generally the easiest to erode.

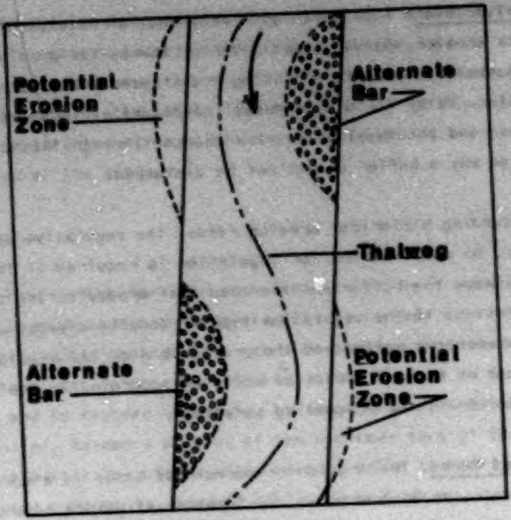


Figure A-11. Schematic of a straight river showing zones of potential erosion.

Larger sized granular material (such as coarse sands, gravels, cobbles) require higher velocities to be eroded because of the increased weight of the particles. With vertical cut banks, large diameter materials often build up at the base of the bank. This build up is because the finer materials holding them in place are eroded away while the larger sized materials cannot be transported. Material finer than fine sands (silts and clays) are often more resistant because of the cohesion between particles.

If the buffer material is uniform throughout, then historical erosion rates do not need to be modified for soil composition effects. If there are areas of significantly finer or coarser sized materials, the historical erosion rate should be modified accordingly based on the discussion in the preceding paragraph.

Vegetative Cover. Vegetation with deep root structures provides a resistance to bank erosion. Dense ground cover on the buffer provides an increase in the roughness of the buffer, causing a decrease in the velocity of flow over the buffer. This, in turn, reduces the potential for erosion of the buffer surface and the development of a channel through the buffer. This is a primary reason why a buffer should not be disturbed.

When extending historical erosion rates, the vegetative pattern should be considered. No compensation for vegetation is required if the vegetation is comparable between the buffer and the area that eroded during the period of historical erosion. If the vegetation type or density changes within the buffer, or between the buffer and the area of historical erosion, then the historical rate of erosion should be modified according to the type of change and the discussion in the preceeding paragraph.

Permafrost Banks. The erosion of permafrost banks is a more complicated process than unfrozen bank erosion. Various investigators have studied the process; some have concluded that permafrost increases bank erosion, others have decided that permafrost decreases bank erosion. Scott (1978) reviewed previous investigations and added his own investigation of five rivers in arctic Alaska. He concluded that the net effect of permafrost is to create greater channel stability than is found in rivers of similar size in nonpermafrost environments. However, banks which are ice-rich will likely have less stability and higher erosion rates than other permafrost or nonpermafrost banks.

When using past records to predict future conditions, the thermal condition of the banks should be considered. Past thermal conditions of the banks are generally not known, consequently, it must be assumed that they were similar to the current condition. If the banks are ice-rich, the safety factor applied to the buffer width should be larger.

Channel Aufeis. Aufeis development in the active channel of a river can cause a larger percentage of the snowmelt runoff to flow across the buffer than otherwise would be expected. Doyle and Childers (1976) show a photograph of this occurring at the Prospect Creek material site near the Trans-Alaska Pipeline. This increased flow can cause erosion of the surface of the buffer, especially any disturbed area. It can also cause scour or headcutting in the material site because of the larger-than-design flows during breakup. The safety factor applied to buffer width should be increased if channel aufeis is known to develop at the site.

BUFFER HEIGHT

Buffer height and buffer width are interrelated to a certain degree. If the buffer is high enough to keep all but the largest of floods out of the material site, only bank erosion needs to be considered in buffer design. This may be the situation for many material sites located on terraces. If the buffer is low and is flooded frequently by larger flows, erosion of the surface of the buffer, headward erosion of the upstream face of the material site, and scour within the site must be considered in the buffer design. The height of natural buffers is fixed at the level provided by nature. Design options include increasing buffer width to account for low height, building up the buffer height by adding a dike on the river side, or building a completely separate buffer structure. These options are discussed in more detail in a subsequent paragraph.

To evaluate the frequency of flooding, hydrologic and hydraulic analyses must be carried out. The details of these analyses are too complex to explain here, but appropriate references are given to allow the user to study the subject further.

- A hydraulic analysis is required to evaluate what discharge will initiate overtopping of the buffer. Cross sections of the river, extending up to the level of the buffer on both banks, are necessary for this analysis. It is preferable to have five or more cross sections through the reach of river adjacent to the buffer. The Manning equation or, perferably, a backwater program, should be used to calculate the discharge corresponding to the stage that would overtop the buffer. Discussions of these analyses are provided in most open-channel hydraulics textbooks (Chow 1959), and in other references (Bovee and Milhous 1978; U. S. Army Corps of Engineers 1976).

- A flood frequency analysis provides an estimate of the recurrence interval or probability of exceedance of the discharge which just overtops the buffer. Detailed discussion of flood frequency analyses are included in most hydrology textbooks, U. S. Water Resources Council (1977), and Lamke (1979). Lamke (1979) provides equations for determining flood discharges for rivers in Alaska for the following recurrence intervals and corresponding exceedance probabilities:

Recurrence interval (years)	Exceedance probability (%)
1.25	80
2	50
5	20
10	10
25	4
50	2
100	1

With the discharge and its frequency of occurrence known, the probability of that flood occurring over the design life of the buffer is needed. Table A-1 below provides the probability of occurrence of a flood of a specified recurrence interval during a specified buffer design life.

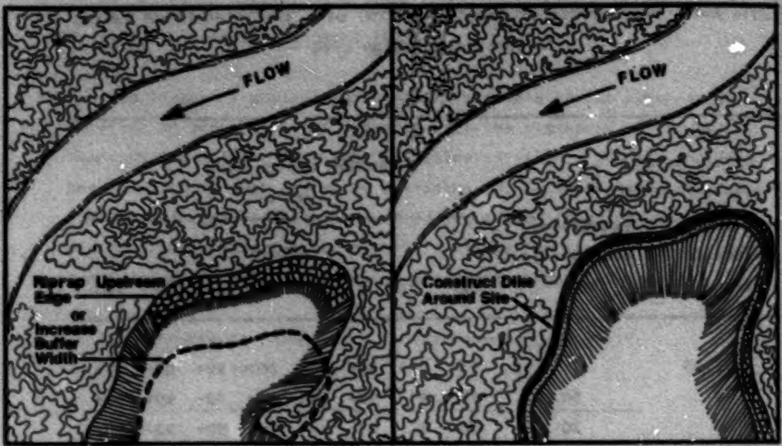
Table A-1. Probability of Occurrance[a] (%) of a Specified Flood During a Specified Design Life

Flood		Buffer design life (years)							
Recurrence interval (years)	Exceedance probability (%)	2	5	8	10	20	25	50	100
1.25	80	96	99+	99+	99+	99+	99+	99+	99+
2	50	75	97	99+	99+	99+	99+	99+	99+
5	20	36	67	83	89	99	99+	99+	99+
10	10	19	41	57	65	88	93	99	99+
25	4	8	18	28	34	56	64	87	98
50	2	4	10	15	18	33	40	64	87
100	1	2	5	8	10	18	22	39	63

[a] Probability of Occurrence = 1 − (1 − Exceedance Probability)$^{\text{Design Life}}$

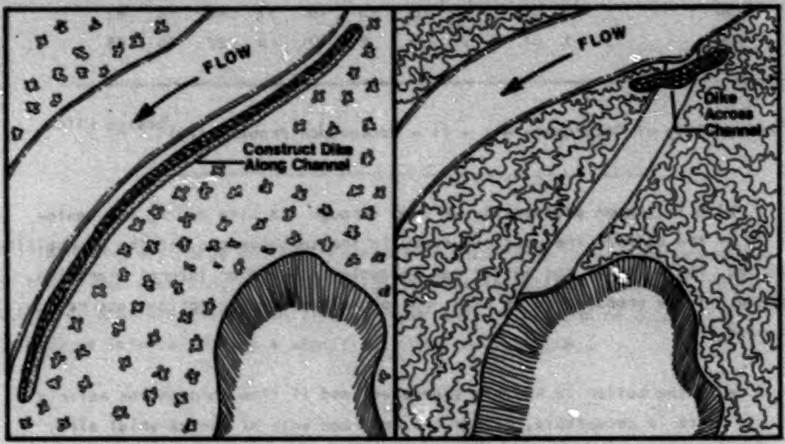
With the known probability of flow through the site during the design life of the buffer, the user can evaluate the consequences. If the probability is low, the width of the buffer can be designed based on lateral migration alone. If the probability is high, one of several design options are recommended.

- If the buffer is heavily vegetated, and if flow through the material site is acceptable, riprap the upstream edge of the material site to prevent headward erosion; or, increase the width of the buffer to allow for erosion loss (Figure A-12a).


FLOW
Riprap Upstream Edge
or
Increase Buffer Width
FLOW
Construct Dike Around Site

a. Heavily vegetated buffer and flow through the site is acceptable.

b. Heavily vegetated buffer and flow through the site is unacceptable.


FLOW
Construct Dike Along Channel
FLOW
Dike Across Channel

c. Lightly vegetated buffer and flow through site is acceptable.

d. Highwater or abandoned channel through heavily vegetated buffer and flow through site is acceptable.

Figure A-12. Schematic of recommended options if the probability of flow through the site is high.

- If the buffer is heavily vegetated, and flow through the site is unacceptable, construct a dike surrounding the material site designed for a flood with an acceptably low probability of occurrence (Figure A-12b).

- If the buffer is lightly vegetated, build a dike along the river side of the buffer designed for a flood with an acceptably low probability of occurrence (Figure A-12c).

- If the buffer contains a high-water or abandoned channel, build a dike along the river side of the buffer to keep flow out of the channel; the dike should be designed for a flood with an acceptably low probability of occurrence (Figure A-12d).

As an example of buffer height design, consider the material site location shown in Figure A-13. The buffer width has been estimated by historical

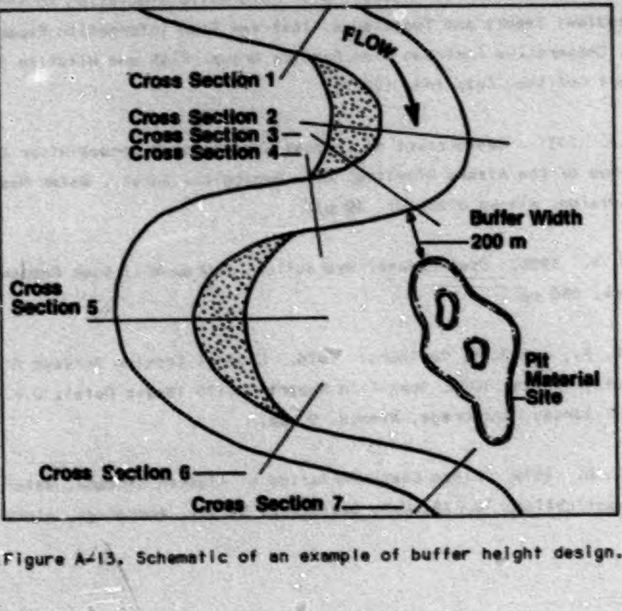

FLOW
Cross Section 1
Cross Section 2
Cross Section 3
Cross Section 4
Buffer Width
200 m
Cross Section 5
Pit Material Site
Cross Section 6
Cross Section 7

Figure A-13. Schematic of an example of buffer height design.

erosion techniques. Cross sections are surveyed as shown (two additional cross sections were collected further downstream). A backwater analysis was run to find that discharges of 103 m^3/s and 89 m^3/s overflowed the buffer at Cross Sections 3 and 7, respectively. A flood frequency analysis indicated that these discharges had recurrence intervals of 35 and 25 years. The design life of the buffer is 25 years. Thus, from Table A-1, at Cross Section 7 there is a 64 percent chance of getting flow into the downstream end of the material site within the 25-year life. This chance is acceptable to the user because the flow would primarily be backwater and would have relatively low erosion potential. At Cross Section 3 the upstream buffer has a 50 to 60 percent chance of overtopping the buffer. The user finds this to be unacceptable, but since there is a relatively small chance of substantial flow entering the pit from the upstream side, he recommends riprapping the upstream bank of the pit.

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U. S. Water Resources Council. 1977. Guidelines for Determining Flood Flow Frequency. Bulletin No. 17A of the Hydrology Committee. Washington. 26 pp. + 14 Appendix.

APPENDIX B

FIELD INSPECTION: DESIRABLE DATA, PROCEDURES, AND EQUIPMENT

APPLICANT SITE PLANNING FIELD INSPECTION

As part of the site planning process the applicant is recommended to visit the proposed site or alternate sites, or both, during the open-water season to gather the following information:

A. Technical data to substantiate aerial photographic interpretation (e.g., sufficient quantity and quality of material, and percent fines).

B. General site specific biological data regarding the presence of areas or species of special concern that may be directly influenced should site development occur.

C. Site specific hydraulic data relevant to site planning and agency review (e.g., discharge, stage, and cross sections).

D. Ground photographs of site physical and biological characteristics which will be used in support of work plan development and submittal to appropriate agencies.

E. If a snow-covered site will be opened, all work area locations should be surveyed during the open-water site visit. This survey should be from reference locations that can be located during site opening. Boundaries, such as those of active channels, buffer locations, vegetated areas, and gravel deposits, can then be accurately relocated during site preparation. This will reduce the potential for damage to areas that should not be disturbed.

F. If winter active-channel mining is contemplated, an additional site visit during winter should be conducted. Its purpose is to determine the presence of water at or below the proposed site.

Field Approach

Material Availability. A variety of techniques are available to evaluate grandular materials present at a site. These include borings, test pits, and resistivity measurements.

Biological Evaluation. The entire site should be walked (during which time ground photos should be obtained) to subjectively assess the overall fish and wildlife habitat quality in sufficient detail to make Decisions I through 4 in Section I B. It may be appropriate to make this a combined applicant-agency site visit.

Hydraulic Data. Cross Sections: Cross sections of the river channel(s) and floodplain should be surveyed to provide input to the hydraulic analysis and the level to which excavation can extend. The number, location, and length of the cross sections should be based on the following criteria (Figure B-1):

- There should generally be at least five cross sections; three or more would generally be necessary to describe the site and one or more would be required upstream and downstream from the site.

- Cross sections through the site should be located at the upstream and downstream ends as well as one or more in between to define the extent of mining.

- In addition to the locations necessary to define the site, cross sections should be located at each significant change in floodplain width.

- The upstream and downstream cross sections should be located at least two active channel-top widths from the upper and lower limits of the material sites and associated buffers.

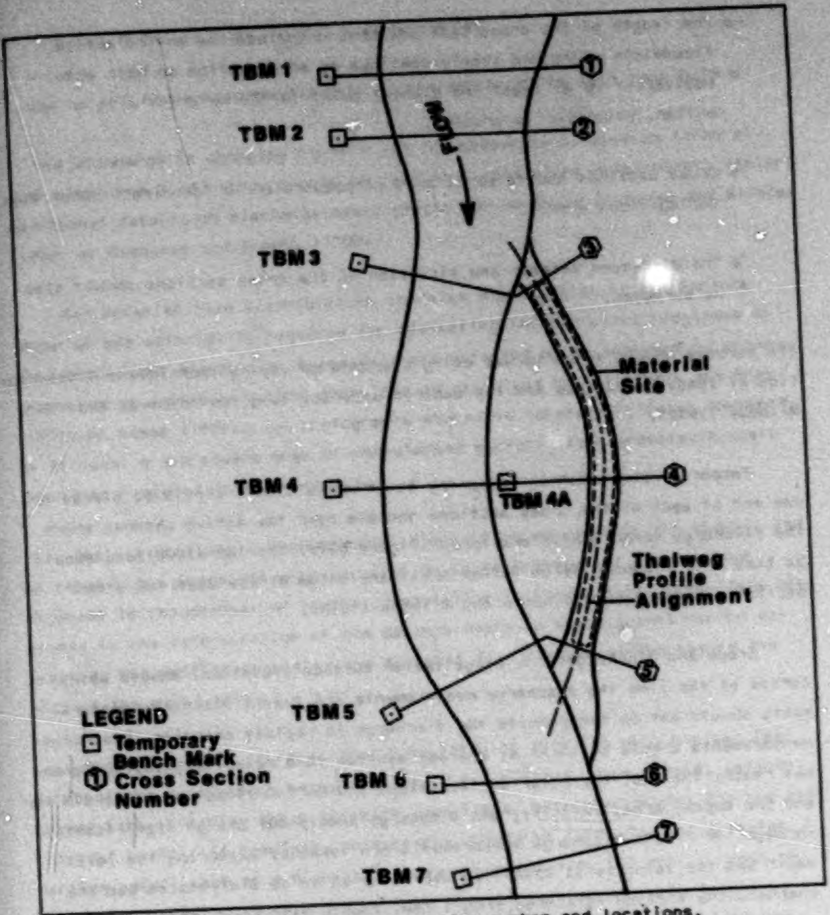
TBM 1
①
TBM 2
②
FLOW
TBM 3
③
Material Site
TBM 4
TBM 4A
④
Thalweg Profile Alignment
TBM 5
⑤
TBM 6
⑥
TBM 7
⑦
LEGEND
Temporary Bench Mark
① Cross Section Number

Figure B-1. Schematic showing cross section number and locations, temporary bench marks and thalweg profile at a hypothetical material site.

- The length of the cross sections should include the entire active floodplain width and should continue to an elevation on both ends equivalent to at least the highest point in the material site or the buffer, whichever is greater.

- Cross sections should be aligned perpendicular to the direction of flow during flood events.

- The distances between and direction of the cross sections should also be surveyed.

The surveys should be performed using standard surveying techniques. A description of these techniques and the desired accuracy is given in Bovee and Milhous (1978).

Temporary Bench Marks: Temporary bench marks (TBMs) should be placed at one end of each of the cross sections and one near the active channel where the discharge measurements are taken (Figure B-1). The TBM elevations should be tied into a common datum (often arbitrary datum at the upstream cross section) as described in Bovee and Milhous (1978).

Stage and Discharge: The stage (water surface elevation) should be recorded at the time the discharge measurements are taken. Discharge measurements should not be taken while the discharge is rapidly changing. Discharge measurements should be taken at a cross section in a relatively uniform channel reach; that is, the water surface slope and bottom slope should be similar and the depth, area, velocity, and discharge should not change significantly through the reach. Discharge measurements are taken by measuring the total depth and the velocity at specified depths at 25 to 30 stations across the channel. The station (distance from a TBM) should also be recorded. Velocity measurements should be taken at the following recommended depths below the water surface relative to the total depth (d):

- 0.2d, 0.6d, and 0.8d is most preferred

- 0.2d and 0.8d is next most preferred

- 0.6d is recommended only if the depth (d) is less than 0.75 m

If the discharge is changing rapidly and the measurements must be taken at that time, the 0.6d method should be used to complete the measurements faster. Additional details on discharge measurements can be found in Bovee and Milhous (1978) or Buchanan and Somers (1969).

Bed Material Size Distribution: The size distribution of the surface layer of bed material is required for evaluating the hydraulic roughness of the channel and floodplain. These data are obtained by an analysis of photographs using a grid-by-number technique as described by Kellerhals and Bray (1971) or Adams (1979). The photographs should be taken, vertically downward, of at least a 1 m square area of undisturbed surface layer gravels. A scale should be included in the photograph.

Thalweg Profile: A thalweg profile should be surveyed of the channel bed at those sites where the material site is being proposed on a gravel bar adjacent to the channel or in the channel itself (Figure B-1). These data are needed in the determination of the maximum depth to which gravel can be extracted. The profile should extend at least five channel widths beyond the ends of the mined site.

Photographs. Photographs should be taken to show the main habitat features of the river reach being studied (e.g., riffles, runs, pools, islands, gravel bars, riparian shrub thickets, mud flats, backwater areas, incised and undercut banks). If possible, photographs should be taken from an elevated vantage point, such as a high bank. A sequence covering the entire reach of stream is desirable. A record should be made of each photograph, including date, time, location, direction of photograph, sequence, and main features being photographed. If the visit is a follow-up to a previous field visit, photographs identical to those obtained previously should be taken, as well as those showing new features. If a winter visit occurs, photograph aufeis and river ice characteristics.

AGENCY FIELD INSPECTION

The initial agency field inspection is recommended to verify the data supplied by the applicant and to gather additional environmental data at the site to identify the significant biological habitats. With this information, any appropriate work plan that minimize environmental impacts can be recommended. The field inspection should evaluate the overall habitat quality and include observations on site-specific parameters including:

- General configuration of the river.
- Channel top width (size of river).
- Stage and discharge.
- Mean velocity.
- Bank and instream cover.
- Substrate.
- Pool:riffle ratio.
- Presence of sensitive areas (i.e., spawning and overwintering areas).
- Dominant terrestrial habitats.

Desirable field inspection equipment for this site visit includes:

- Devices to measure water depth and top width.
- Device to measure water velocity.
- Data sheets of field book for recording field observations.
- 35 mm camera with color slide or print film.
- Dip net.
- Binoculars.

During the initial field visit a site sketch should be prepared perferably using a copy of the aerial photo supplied with the work plan. This sketch should identify major aquatic and turrestrial habitat locations and configurations in relation to the boundaries and configuration of the work area, and locations of special features such as settling basins, stockpiles, access points, and others.

Subsequent agency visits (during site operation and site closure) should measure the same parameters and document habitat alterations.

Field Techniques

Observations. Record and numerate all fish and wildlife encountered in each habitat type.

Stream Velocity. Stream velocity can be estimated by placing a biodegradable object with a density slightly less than that of water (such as an orange or lemon), in the river and recording the time required to travel between two measured points. Express the measurement in feet or meters per second.

Bank and Instream Cover. Bank and instream cover can be expressed as percent of total cover and percent by each category. Categories for which available habitat should be assessed include:

- Banks - undercut bank, overhanging bank vegetation, and near-surface (submerged and emergent) bank vegetation.
- Instream - boulders, logs, large debris, and other velocity barriers.
- Depth - water depth acting as cover such as deep pools and runs.

Substrate. Estimate the percent of substrate composed of the different particle sizes according to the modified Wentworth scale supplied in Appendix H. Separate by pool and riffle.

Photographs. Photographs should be obtained to show the main habitat features of the river reach being studied (e.g., riffles, runs, pools, islands, gravel bars, riparian shrub thickets, mud flats, backwater areas, incised and undercut banks). If possible, photographs should be collected from an elevated vantage point, such as a high bank. A sequence covering the entire reach of stream is desirable. A record should be made of each photograph, including date, time, location, direction of photograph, sequence, and main features. Photographs identical to those obtained previously should be taken, as well as those showing new features if the visit is a follow-up to a previous field visit.

Riparian Zones. These areas provide primary feeding, nesting, and cover habitat for passerines and small and medium sized mammals. During winter they also provide primary overwintering habitat for moose and ptarmigan. Areas that consist of advanced or mature seral stages, generally have well-developed ground cover, shrub layer or overstory cover, or both, (in Northern and Southern interior regions) that provide desirable habitat. Sites that contain riparian zones with high diversity of cover types (herbaceous marsh, mature shrub thickets, mixed shrub thicket-early overstory forest and overstory forest) may be considered more desirable than sites containing riparian zones of homogeneous cover types. Watch for indicators of past activity levels: old passerine nests, small mammal runways and burrows, red squirrel feeding posts, moose browse, and moose and ptarmigan droppings in overwintering areas.

Water Bird Habitat. Feeding, nesting, and cover habitat for waterfowl, shorebirds, terns, and gulls should also be assessed. Determine availability of, and if possible utilization level of:

- Backwater areas, mud flats, and littoral areas as feeding habitat by shorebirds, terns, and waterfowl.
- Pools and side-channels as feeding habitat by terns, gulls, and waterfowl.
- Open and sparsely vegetated gravel bars as nesting habitat by gulls, terns, and shorebirds (most frequently, semipalmated plovers, ruddy turnstones, spotted sandpipers).
- Herbaceous riparian zones as nesting habitat by waterfowl and shorebirds.

Sites with a diversity of water bird habitats are more desirable than sites with only one or two types present.

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APPENDIX C

RIVER-TRAINING STRUCTURES AND BANK PROTECTION DEVICES

INTRODUCTION

River-training structures and bank protection devices may be required during gravel removal operations or site closure, or both. Their purposes can include protection of the site from flow during operation or after closure and reduction of the potential for downstream siltation. River-training structures also may be used to protect the bank of a buffer from excessive erosion. River-training structures and bank protection devices generally should not be used unless absolutely necessary because they usually disrupt natural river processes, often resulting in scour and erosion elsewhere in the system. In addition, bank protection devices can alter banks and their adjacent riparian zones.

Revetments constitute the major group bank protection devices. River-training structures in gravel removal operations primarly consist of dikes; other types of these structures include retards, guide banks, spurs, and jetties. Several publications are available that discuss the design of such structures; these include California Division of Highways (1960); Karaki et al. (1974); Neill (1973); U.S. Army Corps of Engineers (1970) and Winkley (1971). The following paragraphs discuss briefly dikes and revetments.

DIKES

Dikes are long embankments used to control the overflow of water into the material site. Dikes may be constructed along an active channel or across a high-water channel, or both. Dikes may also be used to block active side channels in those cases where the bed is to be scraped. For these purposes, the dikes should be impermeable, high enough to prevent overtopping, and protected from erosion. Impermeable dikes are often constructed of stone or earth, or both.

The design of dikes should include consideration of the following (Figure C-1).

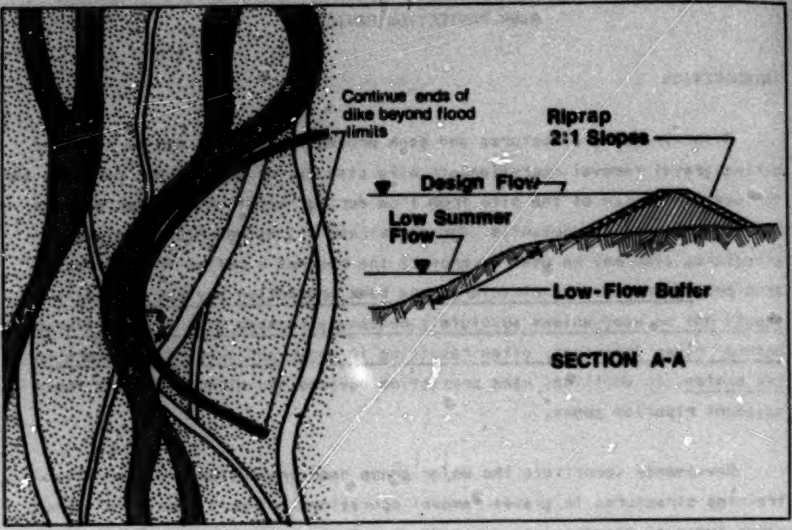

Continue ends of dike beyond flood limits
Riprap
2:1 Slopes
Design Flow
Low Summer Flow
Low-Flow Buffer
SECTION A-A

Figure C-1. Dike design considerations.

- Side slopes should be stable and riprapped to withstand the flood for which they are being designed (generally 2:1 slope is recommended; see revetment design discussion).

- Top width is controlled by the requirements of the equipment constructing the dike.

- The ends of the dike should be located and designed to keep water from flowing around them.

- The top of the dike should be at an elevation equal to that of the water surface of the design flow; this water surface profile should be determined using a hydraulic backwater analysis.

- Dikes should be built beyond the limits of the low-flow buffer.

BANK PROTECTION BY REVETMENTS

A revetment is a layer of erosion resistant material placed on a bank or embankment to armor against erosion. Methods and materials for revetments other than riprap are available but are not discussed here because they generally are unacceptable for environmental reasons.

Riprap

The most common form of revetment is riprap, a layer of rock which may be dumped, hand-placed, or grouted. Dumped rock riprap is most commonly used, although grouted rock riprap may be applicable if the available material is not large enough to meet the requirements of dumped riprap. Rock-filled wire baskets (gabions) may also be used when available materials are of insufficient size to meet dumped riprap requirements. There are several factors important in the design of dumped rock riprap; these include:

- Shape, size, and gradation of the rock.
- Density and durability of the rock.
- Velocity and depth of flow near the rock.
- Steepness of the slope being protected.
- Thickness of the riprap layer.
- Filter blanket presence and design.
- End and toe protection.

These factors are discussed briefly in the following sections.

Shape, Size, and Gradation. The shape, size, and gradation of the rock riprap are the primary properties in resisting erosion. The shape should be angular to provide an interlocking of the rocks. Large rock is more erosion resistant than small rock. Selection of the proper rock size is a complex function of flow characteristics and slope of the embankment being protected. Karaki et al. (1974) present a method for estimating rock size. Neill (1973) presents a graph to use as a guide in selecting riprap size (Figure C-2).

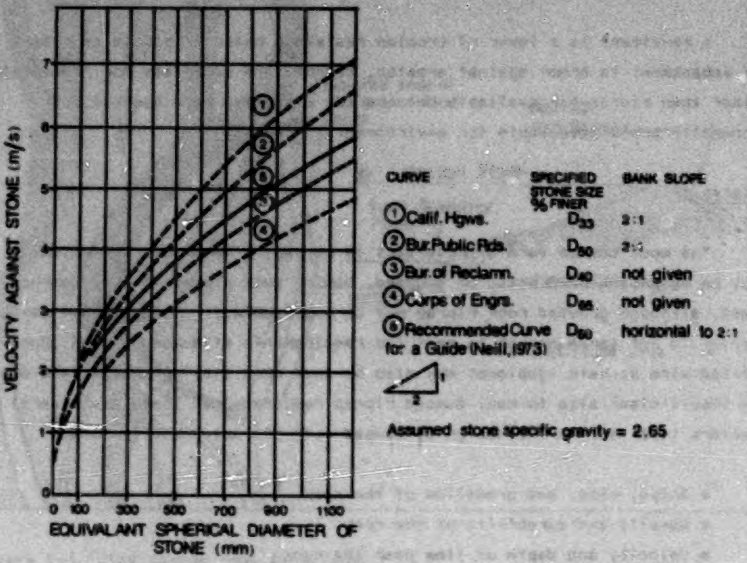


Figure C-2. Graph of riprap size vs. local flow velocity (modified from Neill 1973).

It should be used with caution because not all aspects are incorporated. Well-graded material improves the interlocking of the rock and reduces spaces between rocks. A recommended gradation is shown in Figure C-3.

Density and Durability. The rock used for riprap should be hard, dense, and durable to withstand cycles of wetting and drying, and freezing and thawing. These cycles can cause cracking of the rock, resulting in reduction of size and erosion resistance. Density and durability are generally determined by laboratory tests.

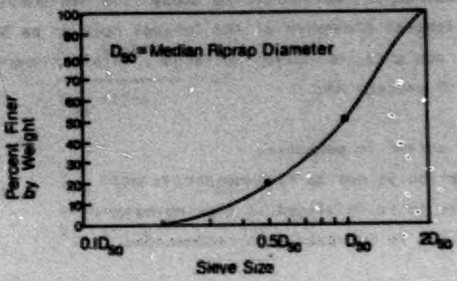


Figure C-3. Suggested gradation for riprap (after Karaki et al. 1974).

Velocity and Depth of Flow. A primary factor influencing erosion is the local velocity of the flow. Direct flow measurements are recommended, but these may be difficult to obtain during flood events. In the absence of measured data, Neill (1973) recommends the local velocity against a slope be taken as:

- Two thirds of the average velocity in straight reaches.
- Four thirds of the average velocity in severe bends.

The shear stress on the rock riprap is proportional to the depth of flow above the riprap. Thus the rock size should increase with increasing depth.

Steepness of Slope. The stability of riprap revetment decreases with increasing steepness of slope. The steepest slope on which riprap will rest without flow forces is the angle of repose of the material, which is generally between 35 and 45 degrees. Flow against the rock will decrease the angle of stability. It is recommended that slopes of 2:1 (2 horizontal to 1 vertical) be used. Slopes steeper than 1.5:1 generally should not be used.

Thickness of Riprap. The thickness of the riprap should be sufficient to provide the desired protection of the slope. The minimum thickness should be equal to the longest dimension of the largest rock or be 50 percent larger than the median rock size, whichever is larger. This minimum thickness should be increased by 50 percent if:

- Wave action is possible.
- Gradation is not as recommended.
- Riprap is to be placed in flowing water.
- A filter is not used when recommended.

Filter Blankets. A filter blanket may be recommended for placement beneath the rock riprap layer to prevent the loss of bank material through the voids in the riprap. If the material washes out, cavities will form beneath the riprap and failure of the riprap revetment can occur. The requirements for a filter depend on the size and gradation of the bank material and on the voids in the riprap layer. If the composition of the bank material is such that it is easily eroded, a filter layer is generally recommended. Poor riprap gradation is also a reason to recommend a filter. Filters may be well-graded gravel or a synthetic filter cloth.

Gravel filters should use gravels ranging from about 5 mm to 90 mm (Karaki et al. 1974). Filter thickness should be no less than 0.15 m; filter thickness equal to half the riprap thickness is recommended. More than one layer, of different gradation and median size, should be considered if there is a very large difference in size between the bank material and the riprap rock. Recommended guidelines for gradation of the filter are given by Karaki et al. (1974); they are summarized in relations below.

These relations should be applied to each layer in turn, starting with the bank material as the fine material and using the needed filter material as the coarse. The first filter selected then becomes the fine material for the next filter layer computation. After determining the size and gradation of each filter, these relations should be used with the last selected filter as the fine material and the riprap as the coarse material. If the results are within the indicated limits, an additional filter layer is not needed.

- $$\frac{D_{50}\ (\text{coarse})}{D_{50}\ (\text{fine})} < 40$$

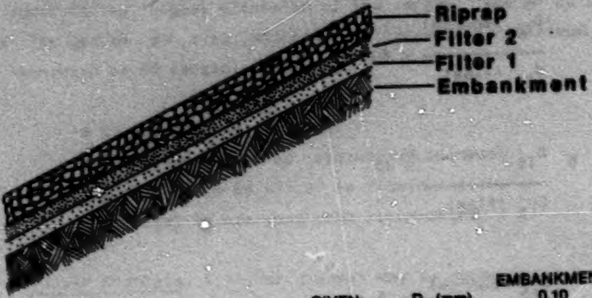
- $$5\ \frac{D_{15}\ (\text{coarse})}{D_{15}\ (\text{fine})} < 40$$

- $$\frac{D_{15}\ (\text{coarse})}{D_{85}\ (\text{fine})} < 5$$

Where D_{50} is median diameter, D_{15} is the diameter particle of which 15 percent of the material is finer, and D_{85} is the diameter particle of which 85 percent of the material is finer. An example of filter gradation design is given in Figure C-4.

Filter cloths have been used with success for more than a decade. They can support large riprap material with no damage to the cloth. A disadvantage of filter cloths is that the riprap must be placed with care to prevent damage to the cloth.

End and Toe Protection. The ends of the riprap revetment along the channel may be subject to erosion. The erosion could remove material from behind the riprap and cause failure of the riprap. Extending the riprap revetment to areas not having erosive velocities is a recommended end protection (Figure C-5a). If this is not possible, the thickness of the riprap layer should be increased to twice that otherwise needed. This extra thickness should be placed in a recess cut into the bank to maintain a uniform riprap face (Figure C-5b).



GIVEN:

	EMBANKMENT	RIP-RAP
D_{15}(mm)	0.10	300
D_{50}(mm)	0.20	500
D_{85}(mm)	0.50	800

STEP 1: FILTER 1 GRADATION DESIGN

D_{50}(FILTER 1) $< 40 \times D_{50}$ (EMBANKMENT) = 8mm

0.5mm = $5 \times D_{15}$(EMBANKMENT) < D_{15}(FILTER 1) $< 40 \times D_{15}$(EMBANKMENT) = 4mm

D_{15}(FILTER 1) $< 5 \times D_{85}$ (EMBANKMENT) = 2.5mm

SELECT $D_{15} = 1.5$mm, $D_{50} = 3.0$mm, $D_{85} = 6.0$mm

STEP 2: FILTER 2 GRADATION DESIGN

D_{50}(FILTER 2) $< 40 \times D_{50}$(FILTER 1) = 120mm

7.5mm = $5 \times D_{15}$(FILTER 1) < D_{15}(FILTER 2) $< 40 \times D_{15}$(FILTER 1) = 60mm

D_{15}(FILTER 2) $< 5 \times D_{85}$(FILTER 1) = 30mm

SELECT $D_{15} = 20$mm, $D_{50} = 40$mm, $D_{85} = 80$mm

STEP 3: CHECK FILTER 2 DESIGN AGAINST RIP-RAP

D_{50}(RIP-RAP) $< 40 \times D_{50}$(FILTER 2)
500mm < 1600mm ✓ OK

$5 \times D_{15}$(FILTER 2) < D_{15}(RIP-RAP) $< 40 \times D_{15}$(FILTER 2)
100mm < 300mm < 800mm ✓ OK

D_{15}(RIP-RAP) $< 5 \times D_{85}$(FILTER 2)
300mm < 400mm ✓ OK

STEP 4: SUMMARY
ACCEPTABLE FILTER GRADATION DESIGN TABLE:

	FILTER 1	FILTER 2
D_{15}(mm)	1.5	20
D_{50}(mm)	3.0	40
D_{85}(mm)	6.0	80

Figure C-4. Example of filter gradation design.

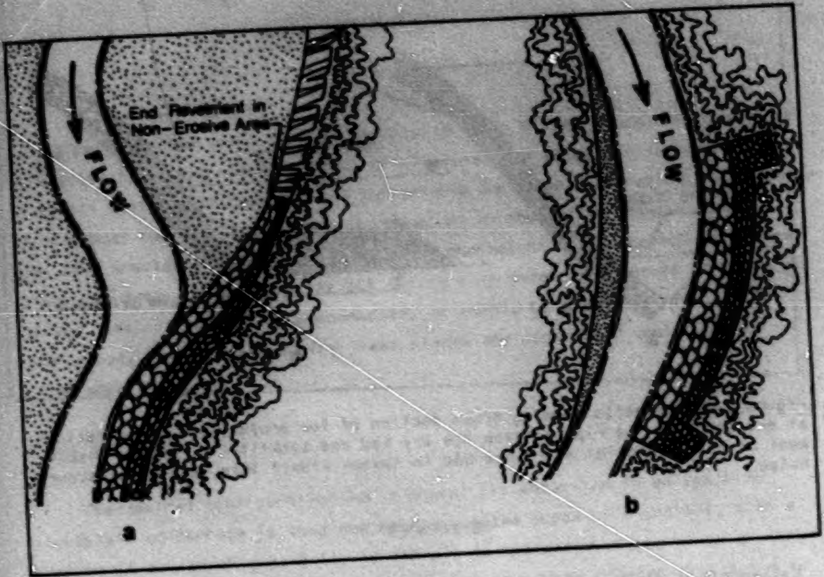


Figure C-5. Schematic showing plan view of end protection configurations: a) extension out of the zone of erosion with a potential reduction in thickness, and b) increasing the thickness at the ends of the revetment.

The base of the riprap revetment can be undercut by scour of the bed if the toe is not protected. Extending the riprap layer below the level of the bed and backfilling is recommended (Figure C-6a). If this cannot be done, the riprap layer should be continued on the channel bed with an increased thickness to provide material to fill any scour holes that develop, thus preventing the scour from undercutting the riprap (Figure C-6b).

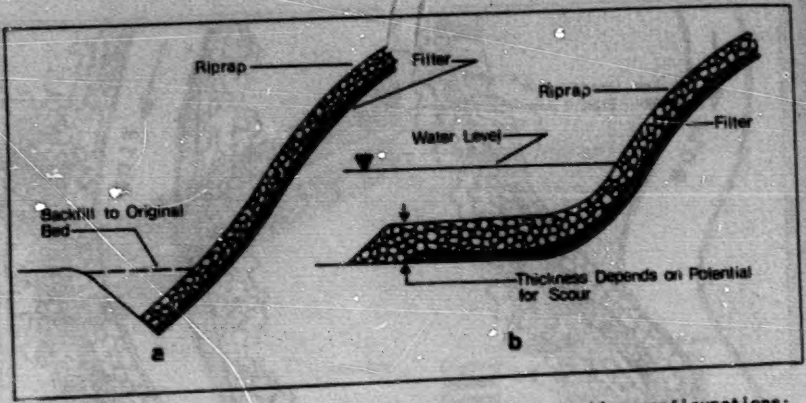


Figure C-6. Schematic showing cross section of toe protection configurations: a) extension of the riprap below the dry bed and backfilling, and b) placement of extra material along the bed to launch itself into developing scour holes.

REFERENCES

California Division of Highways. 1960. Bank and Shore Protection in California Highway Practice. Sacramento: Documents Section, State of California.

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Winkley, B. R. 1971. Practical Aspects of River Regulation and Control, In: River Mechanics, Vol. I. Hsien Wen Shen, ed., Prof. of Civil Eng., Colorado State University.

APPENDIX D

DESIGN OF PITS

There are two basic designs to consider when mining floodplain gravel by pit excavation: pit not connected, or pit connected to an active channel. A properly designed unconnected pit can provide waterfowl, shorebird, and amphibious mammal habitat. If the pit is connected to the active channel, the pit can also provide fish habitat. The outlet channel of the connected pit allows fish that become trapped in the pit during high water to emigrate from the pit at any time. If the pit is unconnected, it should be protected from the 20-year flood. Fish trapped during these floods are considered lost from the river population.

SHAPE AND DEPTH

The desired configuration for a gravel pit excavated in an inactive floodplain or terrace is long and narrow, in the shape of a channel, with a variety of depths (Figure D-1). If the pit is connected to the river or fish are to be stocked in the pit, the mean depth should be greater than 2.5 m to allow fish survival during winter. For a pit with a configuration as shown in Figure D-1, the following are two examples of depth regimes that will result in a mean depth of 2.5 m:

A. For a minimum mean depth with a minimum of littoral area

Mean of depth interval (m)	Percent of pit area
0.5	25
1.5	10
2.5	10
3.5	50
4.5	5

Maximum depth: 5 m

Mean depth: 2.5 m

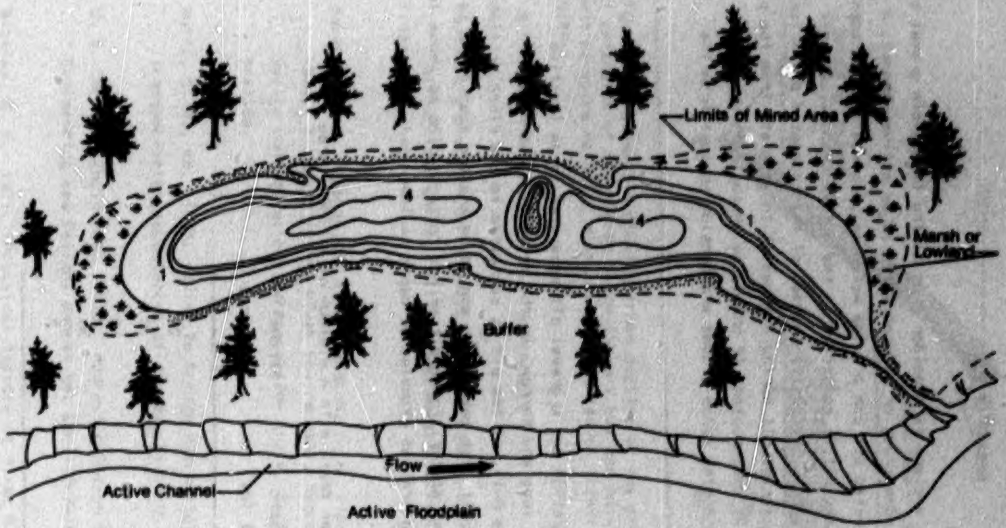
Limits of Mined Area
Marsh or Lowland
4
4
1
1
Buffer
Flow
Active Channel
Active Floodplain

Figure D-1. Desired general configuration of a gravel pit connected to the active channel.

B. For a minimum mean depth with a maximum littoral area

Mean of depth interval (m)	Percent of pit area
0.5	35
1.5	10
2.5	10
3.5	15
4.5	25
5.5	5

Maximum depth: 6.0 m

Mean depth: 2.5 m

A pit with greater littoral area generally allows greater productivity and is preferred for waterfowl, shorebirds, and fish. In both of the above examples an increased mean depth will decrease the probability of fish winter mortality. If more gravel is required, increasing depth is preferred over increasing the surface area of disturbance.

METHOD FOR CALCULATING MEAN DEPTH OF PIT

To obtain an estimate of the mean depth of a designed pit, the following procedures can be used.

A. Determine the 1-m (or other unit of measure) contour intervals for the pit.

B. Determine the percent of surface area(s) consisting of a particular 1-m depth interval [i.e., 0-1 = 0.35; 1-2 = 0.10;...;(n-1)-n = s_n, where n = number of depth intervals].

C. Multiply the midpoint of each 1-m depth interval (d) by the percentage of area composed of that interval [(i.e., d x s = (0.5) (0.35); (1.5) (0.10),...,$(d_n)(s_n)$].

D. Mean depth = sum of all products in C. [i.e., mean depth = Σ ds = (0.5)(0.35) + (1.5)(0.10) + ... + $(d_n)(S_n$].

The Table below contains example calculations of mean depth of the pit shown in Figure D-1. The letters refer to the four steps listed above.

A Contour interval (m)	B Surface area (ha or other unit)	B Surface area (%)	Midpoint of contour interval (m)	C Product of midpoint and percentage area (m)
0-1	1.28	33	0.5	0.17
1-2	0.64	17	1.5	0.26
2-3	0.52	14	2.5	0.35
3-4	1.08	28	3.5	0.98
4-5	0.30	8	4.5	0.36
Total	3.82	100	D	2.12 = mean depth

APPENDIX E

FISH PASSAGE STRUCTURES

PROVIDING FOR FISH PASSAGE OR CULVERT GUIDELINES

Fish passage structures should be provided when it is necessary to cross drainages. Bridges are preferable for fish passage; however, they are often economically unfeasible because of the short project life and remoteness of most floodplain gravel removal operations. If mature timber is available, it may be used for effective and economical log culverts. Metal culverts, although generally undesireable in temporary roads, are usually utilized, but must be installed properly to provide adequate fish passage. The following guidelines on fish passage structures are a synopsis of those developed by Dryden and Stein (1975) and U. S. Department of Agriculture (1979) for the protection of fish resources. The former document presents guidelines to be considered in Northwest Territories road design while the latter deals specifically with how to properly design fish passage structures in Alaska roadway drainages. Refer to these documents for more detail and specifics.

Hydrological Design

Structure Velocities.

A. In general, the average velocity should not exceed 0.9 m/s during fish migration periods. Many species require velocities considerably less than this during migration periods and fish passage can be impeded at velocities of 0.3 m/s (Figure E-1).

B. A 3-day delay period (3 days of velocities in excess of those required for passage) should not be exceeded during the mean annual flood (2.33-year recurrence interval flood). A 7-day delay period should not be exceeded in the design flood.

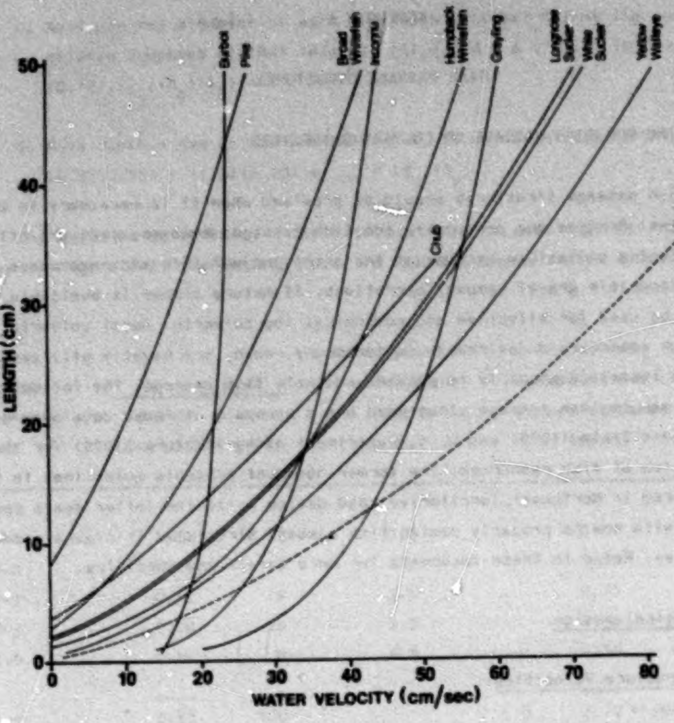

Figure E-1. The relationship between fish fork length and ability to move 100 m against water velocities of 0-80 cm/sec in 10 min. The same curves may also be used to indicate the ability to make progress against these currents over shorter distances. For instance, to cross a 50-m barrier in 10 min the curves should be shifted 8 cm/sec to the right; to cross a 25-m barrier in 10 min the curves should be shifted 12 cm/sec to the right. The line for char is derived from the hypothetical equation $V = 17 L^{0.5}$ and represents the measured value in these experiments (from Jones 1973).

Minimum Water Level. The water level in the culvert should not be less than 20 cm during the open-water season unless fish passage is not required.

Structure Design

Shape.

A. If suitable timber is available, native log stringer or rough-sawed timber bridges and log culverts are the most desirable temporary structures for the passage of fish. They maintain the nctural stream bed and gradient and are easy to remove.

B. Arch culverts with an open bottom are preferred culverts for permanent roads. These culverts retain natural bed material. Closed arch culverts are second in preference.

C. Horizontal ellipse culverts can maintain stream flow width and natural bed material if the culvert invert is placed below the stream bed elevation.

D. Circular culverts are impractical for fish passage unless installed as described by U. S. Department of Agriculture (1979), summarized in the following section.

Installation and Design.

A. Culvert inverts should be laid a minimum of 15 cm below normal stream bed elevation. The Alaska State Pipeline Coordinator's Office often recommends a burial depth of 20% of culvert diameter.

B. Inverts should be designed to prevent hydrostatic uplift at the downstream or upstream end.

C. The culvert gradient should be kept as close to 0% gradient as possible so that upstream or downstream velocity barriers are not created.

Capacity. Culverts should have sufficient capacity to pass the design flood with no backwatering or ponding at the upstream end.

Location.

A. Culverts should not be placed where a channel cutoff or diversion will result.

B. The culvert should be placed so that its discharge is not directed at an unstable bank.

Multiple Culverts. A 1.8 m spacing should be present between adjacent culvert walls. This will provide a downstream backwater area for fish to rest in before attempting passage.

REFERENCES

Dryden, R. L., and J. N. Stein. 1975. Guidelines for the Protection of the Fish Resources of the Northwest Territories During Highway Construction and Operation: Environment Canada. Fisheries and Marine Service Tech. Rept. Series No. CEN/T-75-1. 32 pp.

Jones, D. R. 1973. An Evaluation of the Swimming Performance of Several Fish Species from the MacKenzie River. Dept. Environment, Fisheries and Marine Service, Winnipeg, Man. 53 pp.

U. S. Dept. of Agriculture. 1979. Roadway Drainage Guide for Installing Culverts to Accommodate Fish. Engineering and Aviation Management Division, Forest Service. Alaska Region Report No. 42. 121 pp.

APPENDIX F

SETTLING PONDS AND WASTEWATER TREATMENT

WASTEWATER TREATMENT

The Federal-State effluent guidelines indicate that total suspended solids (TSS) is the main effluent parameter that must be monitored during mining and processing of construction sand and gravel (Hall and Kosakowski 1976). The present EPA requirement is that the TSS of a gravel mining effluent should not exceed 30 mg/ℓ at any time. In order to accomplish this final concentration, a series of settling ponds and often a coagulant are normally required. Specific needs will vary according to the amount of washing necessary and the soil characteristics of the material. In a washing operation, wash water can usually be recycled without need for discharge. In this case the amount of settling required will depend on the need of the operator for clean water. Generally, recycled water with a TSS of less than 200 mg/ℓ is suitable for reuse.

Specific details on how to design and operate settling ponds are discussed in Monroe (1973) and this document should be referenced if additional information is needed. Following is a brief synopsis of his major recommendations.

Settling Ponds - pond with an outlet

A. Used to clarify water for reuse or effluent discharge.

B. Cross-sectional area of the pond must be large so horizontal velocity is very slow.

C. Water must enter pond over most of the width to make the entire pond effective (e.g., to avoid short circuiting, channel formation).

D. The outlet must be wide to skim off the top clear water and maintain a low horizontal velocity.

Filter Ponds - pond without an outlet

A. Used where there is no discharge or recirculation.

B. Water table must be low enough that water will filter out, not into the pond. Pond berms must be high enough to guard against floods.

C. Walls and bottom of the pond must be porous to allow outflow. Ponds seal more slowly if they are kept full so all the area of walls and bottom are working.

D. Pond must be large enough so it will not seal.

E. Coagulants should not be used in filter ponds because they shorten the life of these ponds.

F. It is best to precede the filter pond with a settling pond for heavy particle settlement.

Coagulation

A. Used when there is a high concentration of solids that will not settle or there is limited area for settling ponds, or both.

B. Must be thoroughly mixed to be efficient.

C. Works better in warm water; settlement rate is doubled for every 35°C increase in temperature.

D. Commonly used coagulants are: aluminum sulphate (alum), ferrous sulphate (copperas), calcium hydroxide (hydrated lime), calcium oxide (quick lime), sodium aluminate, sodium carbonate (soda ash), ferric chloride (ferrisul), sodium silicate.

E. Multipond arrangement may be most suitable.

F. Coagulant should be added to the water at inlet to each pond.

REFERENCES

Hall, E. P., and M. W. Kosakowski. 1976. Mineral Mining and Processing Industry. Development Document for Interim Final Effluent Limitations Guidelines and Standards of Performance. Environmental Protection Agency, Effluent Guidelines Division, Office of Water and Hazardous Materials. Wash., D. C. 432 pp.

Monroe, R. G. 1973. Wastewater Treatment Studies in Aggregate and Concrete Production. Environmental Protection Technology Series EPA-R2-73-003. Environmental Protection Agency, Office of Research and Monitoring, Washington, D. C. 108 pp.

APPENDIX G

EFFECTS OF BLASTING ON AQUATIC ORGANISMS

Although infrequently required on floodplain sites, blasting may be utilized during certain phases of gravel removal. Teleki and Chamberlain (1978) developed a series of curves and equations to estimate the fatality radius of a particular charge (based on an explosive with a detonation velocity of 4940-5490 m/s) in relation to certain types of fish (Figure G-1).

A number of studies have evaluated the effects of blasting on a particular organism or groups of organisms. Table G-1 summarizes the results of some of these studies and indicates the range of sensitivities shown by aquatic organisms to pressure changes.

The force generated by a particular charge can be determined at various distances by referring to Table G-2.

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Alpin, J. A. 1947. The effect of explosives on marine life. Calif. Fish and Game 33(1):23-27.

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Hanson, H. 1954. Fur seal control program, Copper River and Bering River area. Alaska Dept. of Fisheries.

Hubbs, C. L., and A. B. Rechnitzer. 1952. Report on experiment designed to determine effects of underwater explosions on fish life. Calif. Fish and Game 38(3):333-366.

Rasmussen, B. 1967. The Effect of Underwater Explosions on Marine Life. Bergen, Norway. 17 pp.

Teleki, G. C., and A. J. Chamberlain. 1978. Acute effects of underwater construction blasting on fishes in Long Point Bay, Lake Erie. J. Fish Res. Bd. Canada 35:1191-1198.

U. S. Navy. 1970. U. S. Navy Diving Manual. NAVSHIPS 0994-001-9010.

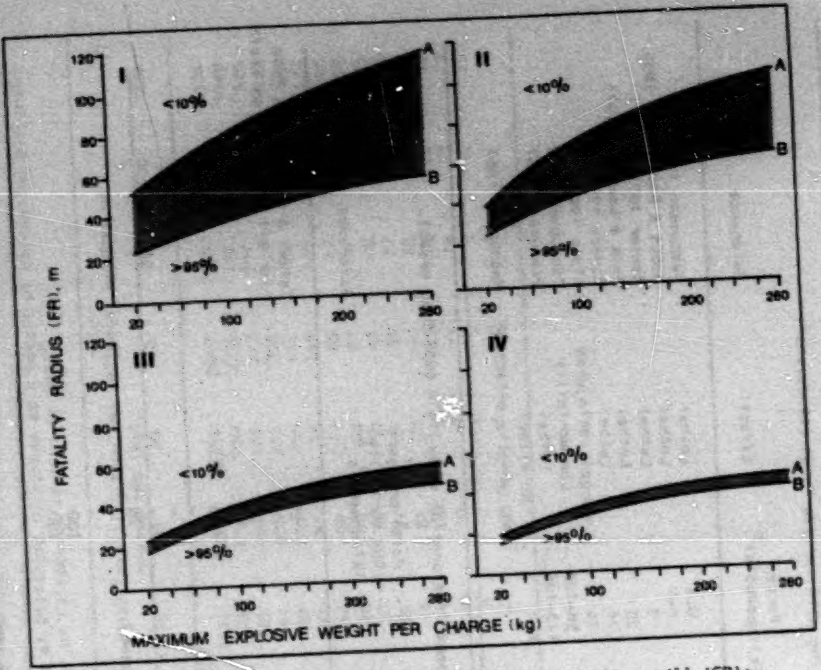

Figure G-1. Relationship of kilogram per charge to fatality radii (FR): A = 10-20% mortality, B = 95% mortality.

I = physoclistic, high lateral compression (pumpkin seed, crappie, white bass).
II = physoclistic, moderate lateral compression (rock bass, smallmouth bass, yellow perch).
III, IV = physostomic, fusiform (III = quillback, white sucker, yellow bullhead; IV = rainbow trout) (from Teleki and Chamberlain 1978).

Equations (From Teleki and Chamberlain 1978)

IA: $\log FR = 1.2423 + 0.3340 \log kg$
IB: $\text{Log } FR = 0.8814 + 0.3390 \log kg$

IIA: $\text{Log } FR = 1.3340 + 0.3337 \log kg$
IIB: $\text{Log } FR = 0.9087 + 0.3323 \log kg$

IIIA: $\text{Log } FR = 0.9261 + 0.3344 \log kg$
IIIB: $\text{Log } FR = 0.8199 + 0.3429 \log kg$

IVA: $\text{Log } FR = 0.8465 + 0.3382 \log kg$
IVB: $\text{Log } FR = 0.7297 + 0.3624 \log kg$

Table G-1. Lethal and Sublethal Blasting Pressures of Selected Aquatic Organisms

A. Blasting with various "high explosives".

Organism	Force (kilopascals)[a]	Effect	Reference
Six month salmon & herring fry	0.4	Lethal	Rasmussen 1967
Fish with air bladder	6–7	Lethal	Hubbs & Rechnitzer 1952
Northern pike	7	Lethal	Baxter 1971
Arctic cisco and small Coregonidae	25	Lethal	Falk & Lawrence 1973
Fur seal	74	Lethal	Hanson 1954
Fish without air bladder	74	Largely uninjured	Alpin 1947
Oyster	56–126	Low mortality	Rasmussen 1967
Blue crab	113–124	Lethal	Rasmussen 1967
Shrimp	169	No effect	–
Salmon and herring fry w/o air bladder	–	"Not greatly affected"	Rasmussen 1967

B. Blasting with "Hydromex" (Detonation velocity = 4938–5486 m/sec).

Organism	Minimum lethal pressure (kilopascals)[a]	Fatal pressure (95% mortality) (kilopascals)[a]	Reference
Pumpkin seed	30	69	Teleki & Chamberlain 1978 (for all organisms on list)
Crappie	30	73	
White bass	30	88	
Gizzard shad	39	–	
Yellow perch	40	73	
Smallmouth bass	65	–	
Rock bass	65	–	
Freshwater drum	73	–	
Quillback	76	76	
White sucker	73	–	
Yellow bullhead	73	–	
Rainbow trout	85	100	
Carp	7	150	

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[a] One kilopascal = 6.896 pounds per square inch.

Table G-2. Force in Kilopascals Expected at Different Distances as a Result of Detonating Different Charges (kg) of Explosives (tetryl or TNT)[a]

Radius from explosion (m)	Force (kilopascals) resulting from the following weights of explosives (kg)									
	1	2	5	10	20	30	40	50	100	200
1	748	942	1279	1611	2030	2324	2558	2755	3471	4374
2.5	299	377	512	645	812	930	1023	1102	1389	1749
5	150	188	256	322	406	465	512	551	694	875
10	75	94	128	161	203	232	256	276	347	437
15	50	63	85	107	135	155	171	184	231	292
25	30	38	51	64	81	93	102	110	139	175
30	25	31	43	54	68	77	85	92	116	146
45	17	21	28	36	45	52	57	61	77	97
60	12	16	21	27	34	39	43	46	58	73
75	10	13	17	21	27	31	34	37	46	58
100	7	9	13	16	20	23	26	28	35	44
150	5	6	9	11	14	15	17	18	23	29
200	4	5	6	8	10	12	13	14	17	22
300	2	3	4	5	7	8	9	9	12	15
500	1	2	3	3	4	5	5	6	7	9

[a] Modified from U. S. Navy 1970.

APPENDIX H

STANDARD FORMULA AND CONVERSION FACTORS

CONTINUITY OF FLOW

$$Q = A_1V_1 = A_2V_2$$

where Q = discharge

A_1 = cross sectional area of the flow at 1

V_1 = mean flow velocity at 1

A_2 = cross sectional area of the flow at 2

V_2 = mean flow velocity at 2

VELOCITY OF CULVERT FLOW

Culvert Flowing Full (Outlet Control)

$$V = \frac{Q}{A}$$

where V = mean flow velocity in culvert

Q = discharge through culvert

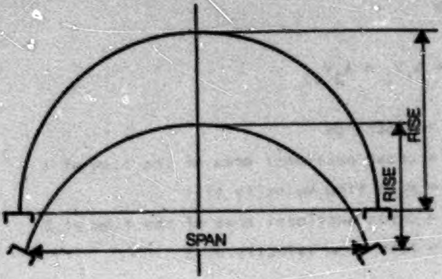
A = cross sectional area of culvert

Cross sectional areas of plate steel arch, pipe-arch, and circular culverts of various sizes are listed in Tables H-1, H-2, and H-3. Estimates of cross sectional areas of circular culverts whose inverts are buried below the stream bed can be obtained from Tables H-1 or H-2, using measured or estimated span and rise values.

Culvert Flowing Partially Full (Inlet Control)

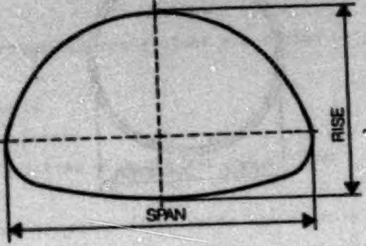
Outlet velocity may be approximated by computing the mean velocity for the culvert cross section using Manning's equation. Manning's equation can be written:

Table H-1. Cross-Sectional Area of Plate Steel Arch Culverts



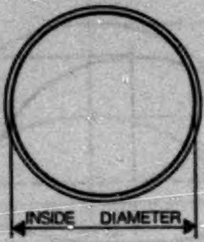
Span		Rise		Cross-Sectional Area	
m	ft-in	m	ft-in	m^2	ft^2
1.83	6-0	0.70	2-3½	0.93	10
2.13	7-0	0.86	2-10	1.39	15
2.44	8-0	1.02	3-4	1.86	20
2.74	9-0	1.18	3-10½	2.46	26½
3.05	10-0	1.35	4-5	3.16	34
3.35	11-0	1.36	4-5½	3.44	37
3.66	12-0	1.52	5-0	4.18	45
3.96	13-0	1.55	5-1	4.55	49
4.27	14-0	1.70	5-7	5.39	58
4.57	15-0	2.01	6-7	6.97	75
4.88	16-0	2.16	7-1	7.99	86
5.18	17-0	2.18	7-2	8.55	92
5.49	18-0	2.34	7-8	9.66	104
5.79	19-0	2.49	8-2	10.96	118
6.10	20-0	2.53	8-3½	11.52	124
6.40	21-0	2.69	8-10	13.01	140
6.71	22-0	2.72	8-11	13.56	146
7.01	23-0	3.00	9-10	15.89	171
7.32	24-0	3.15	10-4	17.47	188
7.62	25-0	3.31	10-10½	19.23	207
7.62	25-0	3.81	12-6	22.95	247

Table H-2. Cross-Sectional Area of Pipe-Arch Culverts



Span		Rise		Cross-Sectional Area	
m	ft-in	m	ft-in	m²	ft²
0.46	1-6	0.28	0-11	0.10	1.1
0.63	2-1	0.41	1-4	0.20	2.2
0.91	3-0	0.56	1-10	0.41	4.4
1.27	4-2	0.79	2-7	0.81	8.7
1.47	4-10	0.91	3-0	1.06	11.4
1.65	5-5	1.02	3-4	1.33	14.3
1.85	6-1	1.40	4-7	2.04	22
2.13	7-0	1.55	5-1	2.60	28
2.41	7-11	1.70	5-7	3.25	35
2.69	8-10	1.85	6-1	3.99	43
2.97	9-9	2.01	6-7	4.83	52
3.25	10-8	2.11	6-11	5.39	58
3.53	11-7	2.26	7-5	6.22	67
3.81	12-6	2.41	7-11	7.25	78
4.09	13-5	2.57	8-5	8.27	89
4.34	14-3	2.72	8-11	9.38	101
4.67	15-4	2.82	9-3	10.13	109
5.00	16-5	3.02	9-11	11.71	126
5.03	16-6	3.35	11-0	13.29	143
5.31	17-5	3.51	11-6	14.68	158
5.66	18-7	3.66	12-0	16.17	174
5.94	19-6	3.81	12-7	17.65	190
6.27	20-7	4.01	13-2	19.88	214

Table H-3. Cross-Sectional Area of Circular Culverts



Inside Diameter		Cross-sectional area	
m	ft-in	m^2	ft^2
0.30	1-0	0.074	0.8
0.46	1-6	0.17	1.8
0.61	2-0	0.29	3.1
0.76	2-6	0.49	5.3
0.91	3-0	0.66	7.1
1.07	3-6	0.89	9.6
1.22	4-0	1.17	12.6
1.37	4-6	1.48	15.9
1.52	5-0	1.82	19.6
1.83	6-0	2.63	28.3
2.13	7-0	3.58	38.5
2.44	8-0	4.67	50.3
2.74	9-0	5.91	63.6
3.05	10-0	7.29	78.5
3.35	11-0	8.83	95.0
3.66	12-0	10.51	113.1
3.96	13-0	12.33	132.7
4.27	14-0	14.30	153.9
4.57	15-0	16.42	176.7
4.88	16-0	18.68	201.1
5.18	17-0	21.09	227.0
5.49	18-0	23.64	254.5
5.79	19-0	26.34	283.5
6.10	20-0	29.19	314.2

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

where V = mean flow velocity in culvert (m/s)

n = Manning roughness coefficient

R = hydraulic radius (m)

S = slope of culvert invert (m/m)

Approximate values of roughness coefficient are listed below:

smooth lined culverts	n = 0.012
corregated metal culverts	n = 0.024
culverts partially filled with gravels and cobbles	n = 0.036

Estimates of the hydraulic radius of culverts can be obtained from Figure H-1. A nomograph for solving Manning's equation and an example problem are given in Figure H-2.

DISCHARGE MEASUREMENTS

Standard Measurement Technique

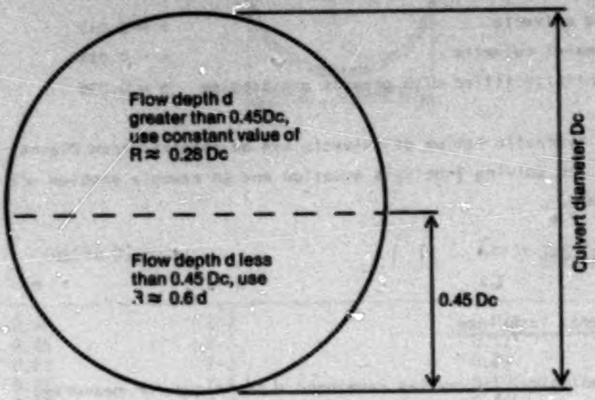
The U. S. Geological Survey has developed a technique for measuring the discharge in a river (Buchanan and Somers, 1969). A relatively straight and uniform reach of river should be selected for taking discharge measurements. The width of the channel(s) should be divided into a number of subsections (25 or more are recommended) that are often, but do not have to be, the same width (Figure H-3). Velocities are measured at each of the observation points at one or more depths depending on the flow depth, desired accuracy, and rate of change of the flow. Generally speaking, the accuracy of the mean velocity increases with increasing number of current measurements at one observation point. An exception to this is when the flow is changing rapidly, thus requiring that the discharge measurements be completed in a short time span. Equations for calculating mean velocity are given in Figure H-3 for three common measurement techniques. Discharge in each subsection is the product of the mean velocity in the subsection and the cross-sectional

Definition of hydraulic radius:

$$R = \frac{A}{P}$$

Where R = hydraulic radius
A = flow cross-sectional area
P = wetted perimeter

Approximate value of hydraulic radius for circular culverts:


Flow depth d greater than 0.45Dc, use constant value of R ≈ 0.28 Dc
Flow depth d less than 0.45 Dc, use R ≈ 0.6 d
0.45 Dc
Culvert diameter Dc

Approximate value of hydraulic radius for arch culverts:

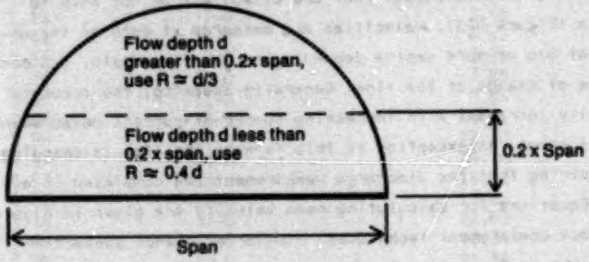
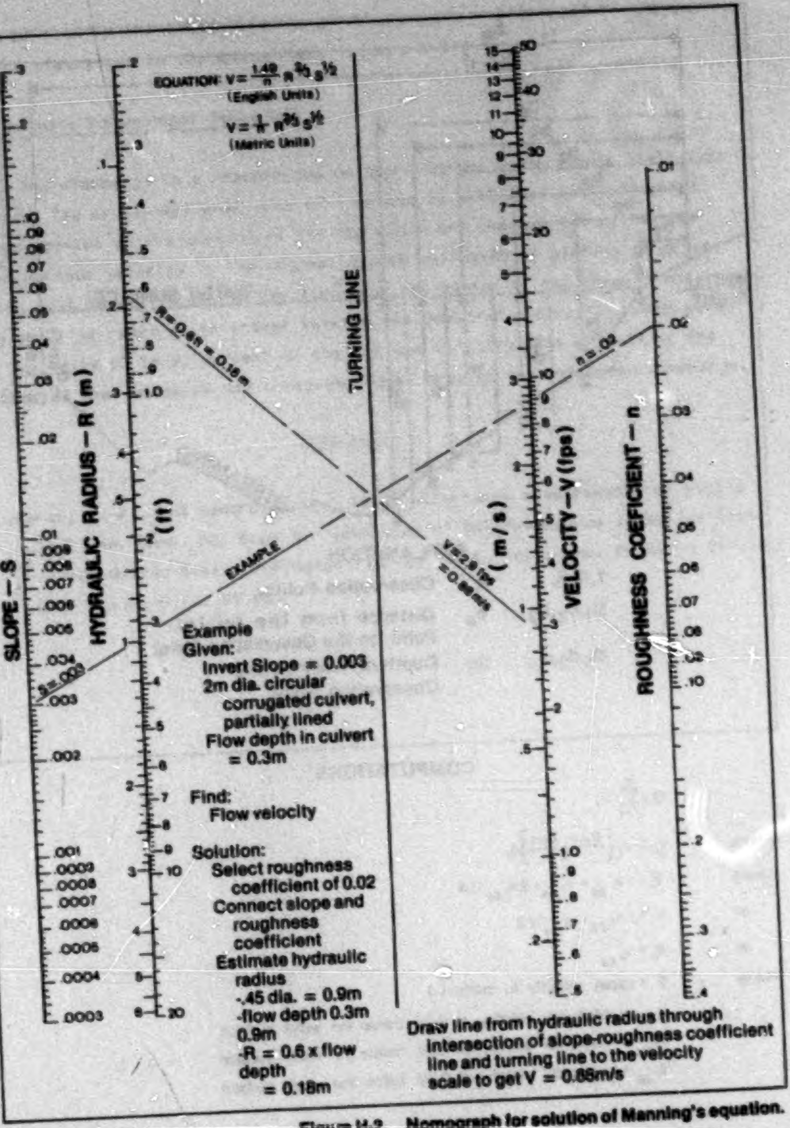

Flow depth d greater than 0.2x span, use R ≈ d/3
Flow depth d less than 0.2 x span, use R ≈ 0.4 d
0.2 x Span
Span

Figure H-1. Methods of estimating hydraulic radius of culverts.



EQUATION: $V = \frac{1.49}{n} R^{2/3} S^{1/2}$
(English Units)

$V = \frac{1}{n} R^{2/3} S^{1/2}$
(Metric Units)

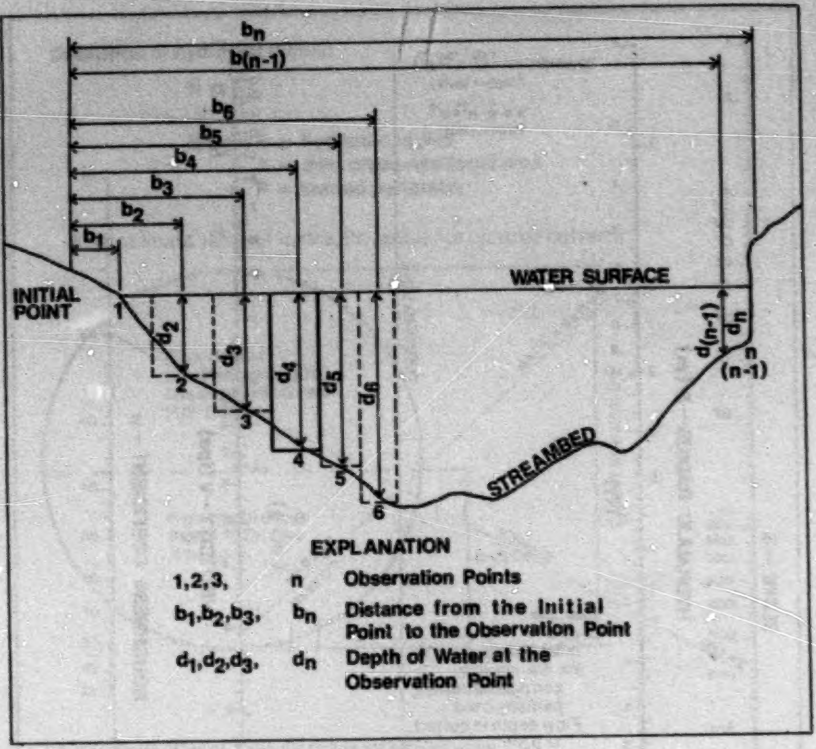
Example
Given:
Invert Slope = 0.003
2m dia. circular corrugated culvert, partially lined
Flow depth in culvert = 0.3m

Find:
Flow velocity

Solution:
Select roughness coefficient of 0.02
Connect slope and roughness coefficient
Estimate hydraulic radius
-.45 dia. = 0.9m
-flow depth 0.3m
0.9m
-R = 0.6 x flow depth
= 0.18m

Draw line from hydraulic radius through intersection of slope-roughness coefficient line and turning line to the velocity scale to get V = 0.88m/s

Figure H-2. Nomograph for solution of Manning's equation.



b_n
$b_{(n-1)}$
b_6
b_5
b_4
b_3
b_2
b_1
WATER SURFACE
INITIAL POINT
1
d_2
2
d_3
3
d_4
4
d_5
5
d_6
6
STREAMBED
$d_{(n-1)}$
d_n
n
(n-1)

EXPLANATION

1,2,3,	n	Observation Points
$b_1,b_2,b_3,$	b_n	Distance from the Initial Point to the Observation Point
$d_1,d_2,d_3,$	d_n	Depth of Water at the Observation Point

COMPUTATIONS

$$Q=\sum_{i=1}^{n} q_i$$

where $q_i=\bar{v}_i\left[\frac{b_{i+1}-b_{i-1}}{2}\right]d_i$

where $\bar{v}_i=(v_{i.2d}+v_{i.8d}+2v_{i.6d})/4$

or $\bar{v}_i=(v_{i.2d}+v_{i.8d})/2$

or $\bar{v}_i=v_{i.6d}$

where $\bar{v}$ = mean velocity in section i

$v_{i.2d}$ = measured velocity at 0.2d below the water surface

$v_{i.6d}$ = measured velocity at 0.6d below the water surface

$v_{i.8d}$ = measured velocity at 0.8d below the water surface

Figure H-3. Discharge measurement technique.

area of flow in the subsection. Total discharge in the channel is the sum of the discharges in the subsections (Figure H-3).

Approximate Measurement Technique

The discharge in a channel can be approximated using simple field techniques. The cross-sectional area of flow can be estimated for the entire cross section as the product of the top width and the average depth. The mean surface velocity in the channel can be estimated by placing an object which just barely floats in the flow near the center of the channel and recording the time required to travel between two measured points. The mean velocity is typically 80 to 90 percent of the surface velocity. The product of the estimated mean velocity and cross-sectional area is the estimated discharge.

REFERENCE

Buchanan, T. J., and Somers, W. P. 1969. Discharge measurements at gaging stations. Chap. A8, Book 3, Techniques of Water-Resource Investigations of the United States Geological Survey, U. S. Government Printing Office, Washington, D. C. 65 pp.

Table H-4. Modified Wentworth Particle Size Scale to be used for Visually Estimating Substrate Composition[a]

Particle description	Size range	
	mm	Inches
Mammouth boulder	>4000	>157 (13 ft)
Very large boulder	2000–4000	78–157 (6.5–13 ft)
Large boulder	1000–2000	39–79 (3.3–6.5 ft)
Medium boulder	500–1000	20–39
Small boulder	250–500	10–20
Large cobble	130–250	5–10
Small cobble	64–130	2.5–5
Very coarse gravel	32–64	1.25–2.5
Coarse gravel	16–32	0.63–1.25
Medium gravel	8–16	0.32–0.63
Fine gravel	4–8	0.16–0.32
Pea gravel	2–4	0.08–0.16
Very coarse sand	1–2	0.04–0.08
Sand	0.062–1	0.0024–0.04
Silt–clay	<0.062	<0.0024

[a] From Bovee, K. D. and R. T. Milhous. 1978. Hydraulic simulation in instream flow studies: Theory and Techniques. U.S. Fish and Wildlife Serv. Instream Flow Info. Paper No. 5. 125 pp.

Table H-5. Conversion Factors

	To convert	into	Multiply by
Length	mm	inches	0.03937
	mm	feet	3.281×10^{-3}
	cm	inches	0.3937
	cm	feet	3.281×10^{-2}
	m	feet	3.281
	m	yards	1.094
	km	miles	0.6214
Area	m^2	square feet	10.76
	m^2	square yards	1.196
	ha	acres	2.471
	km^2	square mile	0.3861
Volume	m^3	cubic yards	1.308
Speed	m/s	feet per second	3.281
Volume flow rate	m^3/s	cubic feet per second	35.31
Mass	kg	pound-mass	2.205
Force	N	pound-force	0.2248
	N	Kilogram-force	0.1020
Pressure	kPa	pound-force per square inch	0.1450
Temperature	°C	°F	9/5 (then add 32)
Concentration	mg/ℓ	parts per million	~1.0

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
Very large boulders	[illegible]
Large boulders	[illegible]
Medium boulders	[illegible]
Small boulders	[illegible]
Large cobbles	[illegible]
Small cobbles	[illegible]
Very coarse gravel	[illegible]
Coarse gravel	[illegible]
Medium gravel	[illegible]
Fine gravel	[illegible]
Very fine gravel	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

APPENDIX I

GLOSSARY

abandoned channel -- A channel that was once an active or high-water channel, but currently flows only during infrequent floods.

active channel — A channel that contains flowing water during the ice-free season.

active floodplain -- The portion of a floodplain that is flooded frequently; it contains flowing channels, high-water channels, and adjacent bars, usually containing little or no vegetation.

aesthetics — An enjoyable sensation or a pleasurable state of mind, which has been instigated by the stimulus of an outside object, or it may be viewed as including action which will achieve the state of mind desired. This concept has a basic psychological element of individual learned response and a basic social element of conditioned social attitudes. Also, there can be ecological conditioning experience because the physical environment also affects the learning process of attitudes.

algae — Primitive plants, one or many-celled, usually aquatic and capable of elaborating the foodstuffs by photosynthesis.

aliquot -- A portion of a gravel removal area that is worked independently, often sequentially, from the other portions of the area.

alluvial river — A river which has formed its channel by the process of aggradation, and the sediment by which it carries (except for the wash load) is similar to that in the bed.

arctic — The north polar region bounded on the south by the boreal forest.

armor layer — A layer of sediment that is coarse relative to the material underlying it and is erosion resistant to frequently occurring floods; it may form naturally by the erosion of finer sediment, leaving coarser sediment in place or it may be placed by man to prevent erosion.

aufeis — An ice feature that is formed by water overflowing onto a surface, such as river ice or gravel deposits, and freezing, with subsequent layers formed by water overflowing onto the ice surface itself and freezing.

backwater analysis — A hydraulic analysis, the purpose of which is to compute the water surface profile in a reach of channel with varying bed slope or cross-sectional shape, or both.

bank — A comparatively steep side of a channel or floodplain formed by an erosional process; its top is often vegetated.

bank-full discharge — Discharge corresponding to the stage at which the overflow plain begins to be flooded.

bar — An alluvial deposit or bank of sand, gravel, or other material, at the mouth of a stream or at any point in the stream flow.

beaded stream — A small stream containing a series of deep pools interconnected by very small channels, located in areas underlain by permafrost.

bed — The bottom of a watercourse.

bed load — Sand, silt, gravel or soil and rock detritus carried by a stream on, or immediately above its bed.

bed load material — That part of the sediment load of a stream which is composed of particle sizes found in appreciable quantities in the shifting portions of the stream bed.

bed, movable — A stream bed made up of materials readily transportable by the stream flow.

bed, stream — The bottom of a stream below the low summer flow.

braided river — A river containing two or more interconnecting channels separated by unvegetated gravel bars, sparsely vegetated islands, and, occasionally, heavily vegetated islands. Its floodplain is typically wide and sparsely vegetated, and contains numerous high-water channels. The lateral stability of these systems is quite low within the boundaries of the active floodplain.

carrying capacity, biological — The maximum average number of a given organism that can be maintained indefinitely, by the habitat, under a given regime (in this case, flow).

carrying capacity, discharge — The maximum rate of flow that a channel is capable of passing.

channel — A natural or artificial waterway of perceptible extent which periodically or continuously contains moving water. It has a definite bed and banks which serve to confine the water.

configuration -- The pattern of a river channel(s) as it would appear by looking vertically down at the water.

contour -- A line of equal elevation above a specified datum.

cover, bank -- Areas associated with or adjacent to a stream or river that provide resting shelter and protection from predators - e.g., undercut banks, overhanging vegetation, accumulated debris, and others.

cover, fish -- A more specific type of instream cover, e.g., pools, boulders, water depths, surface turbulence, and others.

cover, instream — Areas of shelter in a stream channel that provide aquatic organisms protection from predators or a place in which to rest, or both, and conserve energy due to a reduction in the force of the current.

cross section area — The area of a stream, channel, or waterway opening, usually taken perpendicular to the stream centerline.

current — The flowing of water, or other fluid. That portion of a stream of water which is moving with a velocity much greater than the average or in which the progress of the water is principally concentrated (not to be confused with a unit of measure, see velocity).

datum — Any numerical or geometrical quantity or set of such quantities which may serve as a reference or base for other quantities. An agreed standard point or plane of stated elevation, noted by permanent bench marks on some solid immovable structure, from which elevations are measured, or to which they are referred.

dewater — The draining or removal of water from an enclosure or channel.

discharge — The rate of flow, or volume of water flowing in a given stream at a given place and within a given period of time, expressed as cu ft per sec.

drainage area — The entire area drained by a river or system of connecting streams such that all stream flow originating in the area is discharged through a single outlet.

dredge — Any method of removing gravel from active channels.

drift, invertebrate — The aquatic or terrestrial invertebrates which have been released from (behavioral drift), or have been swept from (catastrophic drift) the substrate, or have fallen into the stream and move or float with the current.

duration curve — A curve which expresses the relation of all the units of some item such as head and flow, arranged in order of magnitude along the ordinate, and time, frequently expressed in percentage, along the abscissa; a graphical representation of the number of times given quantities are equaled or exceeded during a certain period of record.

erosion, stream bed — The scouring of material from the water channel and the cutting of the banks by running water. The cutting of the banks is also known as stream bank erosion.

fines — The finer grained particles of a mass of soil, sand, or gravel. The material, in hydraulic sluicing, that settles last to the bottom of a mess of water.

flood — Any flow which exceeds the bank-full capacity of a stream or channel and flows out on the floodplain; greater than bank-full discharge.

floodplain — The relatively level land composed of primarily unconsolidated river deposits that is located adjacent to a river and is subject to flooding; it contains an active floodplain and sometimes contains an inactive floodplain or terrace(s), or both.

flood probability — The probability of a flood of a given size being equaled or exceeded in a given period; a probability of 1 percent would be a 100-year flood, a probability of 10 percent would be a 10-year flood.

flow — The movement of a stream of water or other mobile substances, or both, from place to place; discharge; total quantity carried by a stream.

flow, base — That portion of the stream discharge which is derived from natural storage - i.e., groundwater outflow and the draining of large lakes and swamps or other sources outside the net rainfall which creates the surface runoff; discharge sustained in a stream channel, not a result of direct runoff and without the effects of regulation, diversion, or other works of man. Also called sustaining flow.

flow, laminar — That type of flow in a stream of water in which each particle moves in a direction parallel to every other particle.

flow, low — The lowest discharge recorded over a specified period of time.

flow, low summer — The lowest flow during a typical open-water season.

flow, uniform — A flow in which the velocities are the same in both magnitude and direction from point to point. Uniform flow is possible only in a channel of constant cross section.

flow, varied — Flow occurring in streams having a variable cross section or slope. When the discharge is constant, the velocity changes with each change of cross section and slope.

fork length — The length of a fish measured from the tip of the nose to the fork in the tail.

freeze front — A surface that may be stationary, which has a temperature of 0°C and is warmer on one side of the surface and colder on the other.

frequency curve — A curve of the frequency of occurrence of specific events. The event that occurs most frequently is termed the mode.

gage — A device for indicating or registering magnitude or position in specific units, e.g., the elevation of a water surface or the velocity of flowing water. A staff graduated to indicate the elevation of a water surface.

geomorphology — The study of the form and development of landscape features.

habitat — The place where a population of animals lives and its surroundings, both living and nonliving; includes the provision of life requirements such as food and shelter.

high-water channel — A channel that is dry most of the ice-free season, but contains flowing water during floods.

hydraulics — The science dealing with the mechanical properties of fluids and their application to engineering; river hydraulics deals with mechanics of the conveyance of water in a natural watercourse.

hydraulic depth — The average depth of water in a stream channel. It is equal to the cross-sectional area divided by the surface width.

hydraulic geometry — Those measures of channel configuration, including depth, width, velocity, discharge, slope, and others.

hydraulic radius -- The cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing channel; the ratio of area to wetted perimeter.

hydrograph — A graph showing, for a given point on a stream, the discharge, stage, velocity, or another property of water with respect to time.

hydrology -- The study of the origin, distribution, and properties of water on or near the surface of the earth.

ice-rich material -- Permafrost material with a high water content in the form of ice, often taking the shape of a vertical wedge or a horizontal lens.

impervious -- A term applied to a material through which water cannot pass or through which water passes with great difficulty.

inactive floodplain — The portion of a floodplain that is flooded infrequently; it may contain high-water and abandoned channels and is usually lightly to heavily vegetated.

island — A heavily vegetated sediment deposit located between two channels.

large river — A river with a drainage area greater than 1,000 km^2 and a mean annual flow channel top width greater than 100 m.

lateral bar — An unvegetated or lightly vegetated sediment deposit located adjacent to a channel that is not associated with a meander.

Manning's equation — In current usage, an empirical formula for the calculation of discharge in a channel. The formula is usually written

$$Q = \frac{1.49}{n} R^{2/3} S^{1/2} A.$$

mean flow — The average discharge at a given stream location computed for the period of record by dividing the total volume of flow by the number of days, months, or years in the specified period.

mean water velocity — The average velocity of water in a stream channel, which is equal to the discharge in cubic feet per second divided by the cross-sectional area in square feet. For a specific point location, it is the velocity measured at 0.6 of the depth of the average of the velocities as measured at 0.2 and 0.8 of the depth.

meander wave length -- The average downvalley distance of two meanders.

meandering river — A river winding back and forth within the floodplain. The meandering channel shifts downvalley by a regular pattern of erosion and deposition. Few islands are found in this type of river and gravel deosits typically are found on the point bars at the insides of meanders.

medium river — A river with a drainage area greater than 100 km^2 but less than 1,000 km^2 and a mean annual flow channel top width greater than 15 m but less than 100 m.

microhabitat — Localized and more specialized areas within a community or habitat type, utilized by organisms for specific purposes or events, or both. Expresses the more specific and functional aspects of habitat and cover that allows the effective use of larger areas (aquatic and terrestrial) in maximizing the productive capacity of the habitat. (See cover types, habitat).

mid-channel bar — An unvegetated or lightly vegetated sediment deposit located between two channels.

parameter -- A variable in a mathematical function which, for each of its particular values, defines other variables in the function.

permafrost — Perennially frozen ground.

pit excavation -- A method of removing gravel, frequently from below overburden, in a manner that results in a permanently flooded area. Gravels are usually extracted using draglines or backhoes.

point bar -- An unvegetated sediment deposit located adjacent to the inside edge of a channel in a meander bend.

pool — A body of water or portion of a stream that is deep and quiet relative to the main current.

pool, plunge — A pool, basin, or hole scoured out by falling water at the base of a waterfall.

profile — In open channel hydraulics, it is the water or bed surface elevation graphed aganist channel distance.

reach — A comparatively short length of a stream, channel, or shore.

regional analysis — A hydrologic analysis, the purpose of which is to estimate hydrologic parameters of a river by use of measured values of the same parameters at other rivers within a selected region.

riffle — A shallow rapids in an open stream, where the water surface is broken into waves by obstructions wholly or partly submerged.

riparian — Pertaining to anything connected with or adjacent to the banks of a stream or other body of water.

riparian vegetation — Vegetation bordering floodplains and occurring within floodplains.

riprap - Large sediments or angular rock used as an artificial armor layer.

river regime — A state of equilibrium attained by a river in response to the average water and sediment loads it receives.

run — A stretch of relatively deep fast flowing water, with the surface essentially nonturbulent.

scour — The removal of sediments by running water, usually associated with removal from the channel bed or floodplain surface.

scrape - A method of removing floodplain gravels from surface deposits using tractors or scrapers.

sediment discharge — The volumetric rate of sediment transfer past a specific river cross section.

sinuous river — Sinuous channels are similar to meandering channels with a less pronounced winding pattern. The channel may contain smaller point bars and have less tendency for downvalley shifting. The channels are more stable with respect to lateral shifting.

sinuousity — A measure of the amount of winding of a river within its floodplain; expressed as a ratio of the river channel length to the corresponding valley length.

slope — The inclination or gradient from the horizontal of a line or surface. The degree of inclination is usually expressed as a ratio, such as 1:25, indicating one unit rise in 25 units of horizontal distance.

small river - A river with a drainage area less than 100 km^2 and a mean annual flow channel top width of less than 15 m.

split river — A river having numerous islands dividing the flow into two channels. The islands and banks are usually heavily vegetated and stable. The channels tend to be narrower and deeper and the floodplain narrower than for a braided system.

stage — The elevation of a water surface above or below an established datum or reference.

standing crop — The abundance or total weight of organisms existing in an area at a given time.

straight river — The thalweg of a straight river typically winds back and forth within the channel. Gravel bars form opposite where the thalweg approaches the side of the channel. These gravel bars may not be exposed during low flow. Banks of straight systems typically are stable and floodplains are usually narrow. These river systems are considered to be an unusual configuration in transition to some other configuration.

subarctic — The boreal forest region.

suspended load — The portion of stream load moving in suspension and made up of particles having such density of grain size as to permit movement far above and for a long distance out of contact with the stream bed. The particles are held in suspension by the upward components of turbulent currents or by colloidal suspension.

talik — A zone of unfrozen material within an area of permafrost.

terrace — An abandoned floodplain formed as a result of stream degradation and that is expected to be inundated only by infrequent flood events.

thalweg — The line following the lowest part of a valley, whether under water or not; also usually the line following the deepest part or middle of the bed or channel of a river or stream.

thermokarst — Landforms that appear as depressions in the ground surface or cavities beneath the ground surface which result from the thaw of ice-rich permafrost material.

top width — The width of the effective area of flow across a stream channel.

velocity — The time rate of motion; the distance traveled divided by the time required to travel that distance.

wash load — In a stream system, the relatively fine material in near-permanent suspension, which is transported entirely through the system, without deposition. That part of the sediment load of a stream which is composed of particle sizes smaller than those found in appreciable quantities in the shifting portions of the stream bed.

water quality — A term used to describe the chemical, physical, and biological characteristics of water in reference to its suitability for a particular use.

wetted perimeter — The length of the wetted contact between the stream of flowing water and its containing channel, measured in a plane at right angles to the direction of flow.

wildlife — All living things that are neither human nor domesticated; most often restricted to wildlife species other than fish and invertebrates.

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Small	Medium	Large	Active floodplain	Inactive floodplain	Terrace	Active channel	High-water channel	Abandoned channel	Bed	Point bar	Lateral bar	Mid-channel bar	Inside meander	Outside meander	Vegetated island	Vegetated bank
River size			Site location			Associated channel			Type of deposit							

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16. Abstract (Limit: 200 words)

A 5-year investigation of the effects of floodplain gravel mining on the physical and biological characteristics of river systems in arctic and subarctic Alaska is described. Twenty-five sites were studied within four geographic regions. The sites were selected such that within each of the regions the group of sites exhibited a wide range of river and mining characteristics. The field data collection program covered the major disciplines of hydrology/hydraulics, aquatic biology, water quality, and terrestrial biology. In addition, geotechnical engineering, and aesthetics site reviews were conducted. A wide range of magnitude and type of physical and biological changes were observed in response to mining activity. Little change was observed at some sites, whereas other sites exhibited changes in channel morphology, hydraulics, sedimentation, ice regime, aquatic habitat, water quality, benthic macroinvertebrates, fish utilization, vegetation, soil characteristics, and bird and mammal usage.

Two major products of the project are a Technical Report which synthesizes and evaluates the data collected at the sites, and a Guidelines Manual that aids the user in developing plans and operating material sites to minimize environmental effects.

17. Document Analysis a. Descriptors

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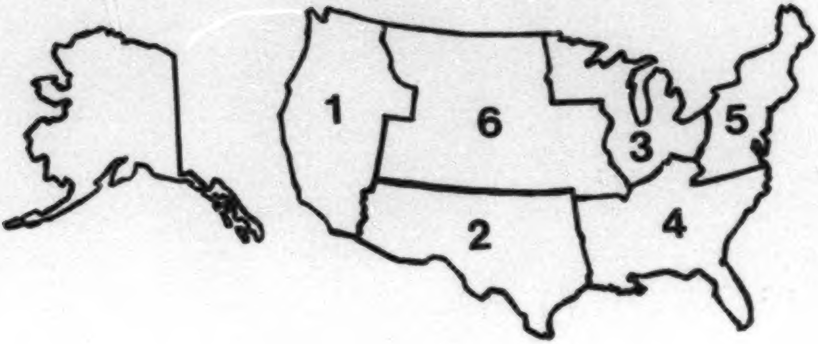

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